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FINAL REPORT

IMPACT OF CROP ROTATION AND TILLAGE ON DISEASES OF FIELD CROPS

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Project Title: Impact of Crop Rotation and Tillage on Diseases of Field Crops

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1. Abstract/Summary

The long-term impact of reduced tillage and rotation on plant diseases of winter wheat, spring wheat, and pea were monitored under conventional, minimum, and zero tillage systems for 12 years at one site in south-eastern Saskatchewan. The severity of leaf spots on wheat and pea and root rot of pea was not significantly affected by tillage or rotation practice. Mycosphaerella blight of pea was slightly reduced with conventional tillage in 3 years of the study. The severity of leaf spot diseases on wheat (tan spot and septoria leaf blotch) were similar under reduced tillage in 8 of the years. In the years when differences occurred, severity was slightly higher under reduced tillage, but yield was reduced only in one year. Root rot severity in wheat was slightly lower under reduced tillage in most years. Although the relative importance of pathogens in the complex changed (*Cochliobolus sativus* and *Gaeumannomyces graminis* decreased; *Fusarium* species increased), disease severity was only slightly affected. Rotation had a larger impact on wheat yield than most diseases. Growing spring wheat after summerfallow or pea reduced foliar disease severity and increased yield. However, the use of flax as a broad-leaved crop in rotation with wheat increased the incidence of *Fusarium* species in wheat. Most other diseases and pathogen species were lower in rotations alternating years of cereal and broad-leaved crops than in rotations with cereals and summerfallow. Rotations using more broad-leaved crops had improved wheat yield over those with a summerfallow-cereal system.

2. Executive Summary

Throughout the 1990's, the use of reduced tillage practices have increased in western Canada. With some environments, these practices have the potential to increase the severity of some important plant diseases because of the increased residue left on the soil surface. Growers are demanding information on the impact of tillage and rotation on diseases in Saskatchewan. They know that reduced tillage practices help protect the soil and conserve moisture. They also understand that better management of plant diseases can reduce losses in crop yield by 5-30%

and preserve seed quality. Years that are conducive to the development of high disease levels can cost Saskatchewan producers up to $425M in yield and an equivalent amount from downgrading of seed quality. Providing producers with information on the most appropriate cropping practices to manage disease problems will return improved value through higher yields, reduced pesticide inputs, and increased income stability.

With these factors in mind, a tillage and rotation study initiated at Indian Head, Saskatchewan in 1987 has continuously monitored diseases of spring wheat, winter wheat, and pea grown in three different rotations each under conventional, minimum, and zero tillage practices. The rotations were: a) fallow - spring wheat - spring wheat - winter wheat, b) spring wheat - spring wheat - flax - winter wheat, and c) peas - spring wheat - flax - winter wheat. This project is one of the longest running rotation studies in western Canada where plant diseases have been continuously monitored. The results from the first cycle (1987-1990) were published by Bailey et al. 1992. The results from the second (1991-1994) and third (1995-1998) rotation cycles are included in this report.

This 12 year project has demonstrated that new or unusual disease problems did not develop with the long-term use of reduced tillage in south-eastern Saskatchewan. Typically, foliar leaf spot diseases and common root rot occurred every year, while occasionally take-all appeared in some years depending on environmental conditions. These plant diseases were associated with wheat yield losses in 4 of 7 years evaluated. The major pathogens of pea were mycosphaerella blight on the leaves and fusarium root rot.

At the completion of the second and third rotation cycles, reduced tillage practices did not significantly increase the severity of foliar diseases in wheat, nor did it increase the incidence of the fungal species causing leaf spotting during the growing season. During the first cycle of the study, leaf spot severities were slightly higher with reduced tillage in one of four years and in none of the years during the second cycle. During the third rotation cycle, leaf spot severity slightly increased with reduced tillage in two of the four years, but yield was only reduced in one of those years. Therefore, reduced tillage practices had little impact on the disease severity or yield loss in wheat.

Over all years of the study, tillage had a greater impact on the root diseases of wheat and their pathogen populations than on the foliar diseases. In years when the pathogens were present, *C. sativus* (causing common root rot) and *G. graminis* var. *tritici* (causing take-all) were significantly less prevalent and disease was less severe with reduced tillage practices in 6 of 11 years and 3 of 4 years, respectively. The incidence of *Fusarium* spp. increased with reduced tillage in only 2 of the 7 years it was isolated from Cycle 2 and Cycle 3, but this same trend was observed more frequently in another study conducted at the same site. Despite the change in the relative importance of the root pathogens, the expression of symptoms (i.e. disease severity) remained at similar levels under all tillage systems.

The most diverse crop rotation using both broad-leaved and cereal crops (i.e. pea-spring wheat-flax-winter wheat) provided the greatest gains in wheat yield, whereas the summerfallow-cereal based system produced the lowest yields in 5 of 8 years during both Cycle 2 and Cycle 3. Oddly, in our study, there were few, consistent differences in disease severity or the prevalence of most pathogens in these rotations during the three cycles. An

important observation to note was in 3 of 7 years, the incidence of *Fusarium* species from wheat roots was higher in the rotations using the broad-leaved crops, whereas *C. sativus* decreased in those situations. Upon closer examination, it appeared that certain cropping sequences within a planned rotation influenced the pathogens. *Fusarium* species were more abundant in wheat following another cereal or flax and less abundant after summerfallow, chem-fallow, or pea. Low foliar disease severities were observed on spring wheat after summerfallow (and chem-fallow) or after pea in 10 of 11 years. The crop sequence that increased foliar disease severity was spring wheat after spring wheat in the summerfallow-cereal crop rotation (3 of 4 years in Cycle 3).

In field pea, *Mycosphaerella pinodes* (Berk & Blox.) was the dominant foliar pathogen and fusarium root rot (*Fusarium* spp.) was the dominant root disease at the site each year. There were no substantial differences in incidence or severity of either disease among tillage treatments. Conventional tillage resulted in a small decrease in severity compared to reduced tillage in both 1993 and 1994. In 1995, mycosphaerella blight severity was low throughout the season, and blight severity under zero-tillage was slightly higher than for the other two tillage regimes. In 1996, blight severity was low to moderate, and there were no differences among tillage systems. There were no differences in fusarium root rot severity or yield among tillage treatments in any year. Pea yields were similar among tillage treatments in all years. No other differences were noted.

The implications of this research are significant for Saskatchewan. For wheat and pea grown in south-eastern Saskatchewan, tillage method should not increase the common foliar diseases sufficiently to result in yield reductions. To reduce foliar diseases of wheat, it should be grown after either summerfallow, chem-fallow, or pea. Reduced tillage practices may be used to lower the levels of common root rot and take-all in wheat. Combining reduced tillage in cereals with increasing broad-leaved crop diversity will also lower the risk of these diseases and increase yield. However, it is important to note that the relative proportion of the root pathogen species in the soil and on the crop residue changes with these practices. *Fusarium* species on wheat increased by 10% with reduced tillage and with the use of broad-leaved crops, particularly flax. Flax is also a host for many *Fusarium* species. The higher levels of *Fusarium* inoculum may pose an increased risk of diseases such as prematurity blight and fusarium head blight, if the environmental conditions favour their development because larger quantities of inoculum are present. In this study, those types of conditions were never encountered and those diseases were not observed. Producers in areas where there is a higher chance of fusarium-related diseases occurring, may wish to consider more conventional tillage practices and not growing wheat after wheat or wheat after flax to help reduce the risks. If fusarium-related diseases are not of immediate concern, then based on the crops used in this study, the most successful rotation would use a non-cereal crop such as pea or flax alternating between years with a cereal crop, such as either spring or winter wheat.

3. Technical Report

3a. Background and Objectives

On the Canadian prairies, tillage and rotation practices vary widely, but there are increasing trends to

change from traditional, high-tillage, summerfallow-cereal based cropping systems to reduced or zero tillage practices combined with greater broad-leaved crop diversity in the rotation. With these practices, it was hypothesized that greater problems would occur with residue-borne pathogens since reduced tillage places greater quantities of residue on the soil surface where it takes longer to decompose. To determine the impact of various tillage practices with different cropping systems on plant diseases, a study was initiated at a site in south-eastern Saskatchewan in 1987. During the first 4-yr rotation cycle, tillage had little influence on increasing foliar disease severity in wheat or pea, although cereal root disease severity often decreased with zero tillage (Bailey et al. 1992). However, the long-term impact of reduced tillage with different cropping systems on the diseases remained unknown. Therefore, the dynamics of disease severity and changes in the populations of causal agents were monitored in the second (1991-1994) and third (1995-1998) rotation cycles.

3b. Materials and Methods

The study was conducted on a heavy clay, thin black soil at the Agriculture and Agri-Food Canada Experimental Farm, Indian Head, SK. The tillage systems used were conventional with fall and spring tillage operations, minimum with one tillage operation in the spring before seeding, and zero with soil disturbance only at seeding and no tillage operations were performed. The rotations used were: 1) summerfallow-spring wheat-spring wheat-winter wheat, 2) spring wheat-spring wheat-flax-winter wheat, and 3) pea-spring wheat-flax-winter wheat. The study design was a split plot with tillage systems as the main plots, crops in rotation as the subplots, and with four replications.

Visual disease severity on leaves and roots of spring wheat and winter wheat were estimated on 25 plants collected at random from a diagonal path across each plot between July 15 and August 20 in all years. Data were not collected in 1991. Root disease severity was estimated on the subcrown internode of each plant using a 0-3 scale, and the mean severity per plot was calculated. Subcrown internode and crown pieces from each plant were washed for 1 hr under running tap water, then dried on absorbent paper. The root pieces were disinfested with 0.5% NaOCl for 3 min, rinsed twice with sterile distilled water, and then plated on minimal media containing 100 mg/L streptomycin sulfate and 50 mg/L vancomycin hydrochloride. The plates were incubated at 20°C and 12 hr day. The percentage of plants infected with red *Fusarium* spp. (not identified to species level) and *Bipolaris sorokiniana* (Sacc.) Shoem., was recorded 7-9 days after plating. *Gaeumannomyces graminis* (Sacc.) von Arx & Olivier var. *tritici* Walker was isolated on semi-selective media containing L-DOPA which produces a black pigmentation in the medium under the infected tissue. The lower half inch of the main stem was surface sterilized with 1% silver nitrate for 30 seconds followed by two sterile distilled water rinses and blotted dry before plating. Plates were incubated at 20°C with 12 hours daylight for 5 days.

Leaf spot severity on cereals was assessed using a 0-11 scale, where 1 represents slight disease in the lower plant canopy and 11 is severe disease in both the lower and upper plant canopies, based on a modified scale from Couture (1980). The flag leaf and penultimate leaf from 10 plants per plot were cut into 4-cm-long segments.

These leaf pieces were washed in running water for 1 hr, disinfected for 1 min with 0.5% NaOCl, then plated on water agar containing 100 mg/L streptomycin sulfate and 50 mg/L vancomycin hydrochloride. The plates were incubated for 1 wk under a mixture of black light, black-blue light, and cool white fluorescent light. Fungal cultures were identified based on sporulation. Colonies of *Stagnospora nodorum* (Berk.) E. Castell. & Germano, *Septoria tritici* Roberge in Desmaz., *Pyrenophora tritici-repentis* (Died.) Drechs., and *Cochliobolus sativus* (Ito & Kurib.) Drechs. ex Dast. on each 4-cm segment were counted. The prevalence of a species was calculated by the number of colonies per unit area for that species, divided by the total colonies per unit area, and then expressed as a percentage.

In the spring of 1993, ten plants from the wheat stubble residue of the previous year (1992 wheat crop) were randomly collected from plots on May 19 to determine which pathogens were more prevalent early in the spring immediately after an overwintering period. Each plant was divided into a below-ground sample for identification of root pathogens and an above-ground sample for identification of foliar pathogens. The isolations methods used are described above.

In field pea, foliar and root rot incidence and severity were assessed on June 09 (seedling stage), July 14 (flowering) and August 10 (seed-filling) in 1993 and on July 14 (late-flower), August 10 (seed filling) and August 30 (maturity) in 1994. No assessments were made in 1991-92. In the third cycle, foliar and root rot incidence and severity of field pea were assessed on June 20, July 14 and August 16 in 1995; July 15 and August 15 in 1996; July 23 and August 6 in 1997; and July 7, July 21 and August 6 in 1998. On each sampling date, 25 plants were collected (5 plants per location, 5 locations per subplot) and rated for foliar and root disease severity. Foliar diseases were rated using the Horsfall-Barrett scale (Horsfall and Barrett 1945). In addition, whole-plot foliar disease ratings were made at flowering and seed filling. Root rot was assessed using a 0-3 scale, where 1 represents 1-25% of the tap root diameter rotted, and 3 represents > 50% rotted (modified from Hwang et al. 1994). For all diseases, pathogens were identified based on symptoms and identification was confirmed by occasional plating of surface-disinfested samples onto PDA.

Differences in the pathogen populations and disease severity in each year were compared using analysis of variance, with *a priori* means comparisons. Analyses could not be made across years as there were large differences among years. Stepwise linear regression was used to evaluate the associations between yield and disease (SAS User's Guide: Statistics Version 5, 1985, Cary, N.C.).

3c. Observations : Rotation Cycle Two, 1991-1994

Tillage had no impact on foliar and root disease severity or yield of wheat from 1992-1994 (Table1). The impact of rotation on disease showed inconsistent trends in wheat (Table1). The highest yields in wheat were obtained with the rotation using the greatest number of broad-leaved crops (pea-spring wheat-flax-winter wheat) (Table 1). The lowest yields in wheat occurred with summerfallow-spring wheat-spring wheat-winter wheat (2/3 yr) and spring wheat-spring wheat-flax-winter wheat (3/3 yr). Analysis of variance indicated no interaction between tillage

practices and rotations. Examination of the individual crops grown in sequence showed that foliar disease severity and yield were greater in winter wheat than spring wheat (Table 2). Among the spring wheat treatments, yield was highest after either summerfallow or pea in all years; foliar disease severity was lowest (only in 1993) following these treatments.

Disease severity varied with the annual growing season environment which was measured on site. Foliar disease severity was lower in 1992 than in 1993-1994 (Table 2) which corresponded to seasonal precipitation. The growing season precipitation from May to August, 1992 was below the 82-year average (225mm) with only 208mm precipitation and above the average in 1993 and 1994 with 255mm and 279mm, respectively. Cooler than average temperatures resulted in low to low-moderately low root disease severity in all years. The growing degree days from April to September ranged from a low of 1179 to a high of 1407 compared to the long-term mean of 1659.

The prevalence of leaf-spotting fungi on wheat during the growing season was not affected by tillage practice, but it did affect the prevalence of some root pathogens (Table 3).The incidence of *B. sorokiniana* and *G. graminis* var. *tritici* decreased with zero tillage, but there was no affect on *Fusarium* spp. Rotation had little impact on the prevalence of most wheat pathogens. The exceptions were lower levels of *S. tritici* (1993 only), higher levels of *Fusarium* spp. (1992 and 1994) and lower levels of *C. sativus* (1994) in the rotations using broad-leaved crops compared to continuous wheat with summerfallow (Table 3). Stepwise linear regression showed that disease had no significant impact on wheat yield in 1992 and 1993. In 1994, wheat yield was reduced by *S. tritici* and *G. graminis* var. *tritici* (yield= $-123_{St} - 833_{Gg} + 2690$, $R^2 = 0.4$, $P<0.03$).

Isolation of pathogens from the residue of wheat stubble plants early in the spring showed that *S. nodorum* was the only pathogen more prevalent under zero tillage (3 lesions per 4 cm tissue) than conventional tillage (0.7 lesions) after an overwintering period (LSD-test, P=0.05). *S. nodorum* sporulates most heavily on residue left on the soil surface for one overwintering period relative to residue that is either buried or left on the surface for two or more overwintering periods (Duczek et al. 1999).

The occurrence of the foliar pathogens on the wheat stubble residue following an overwintering period was not affected by rotation. The incidence of *Fusarium* spp. was highest in the rotations with broad-leaved crops (Sw-Sw-Fl-Ww, 31%; Pe-Sw-Fl-Ww, 28%) compared to continuous cereals with summerfallow (Sf-Sw-Sw-Ww, 18%, LSD-test, P=0.05). When the previous crop was either spring wheat, winter wheat, or flax, the incidence of *Fusarium* from lowest to highest ranged from 23-40%. When the previous crop or treatment was pea, chem-fallow or summerfallow, the incidence of *Fusarium* ranged from 0-7%. This suggests that the *Fusarium* spp. present were more pathogenic to wheat and flax than pea. It also suggests that the use of herbicides (as with chem-fallow) or increased tillage (as with summerfallow) may have role in decreasing *Fusarium* populations in the soil. The incidence of *C. sativus* was highest in the rotation with continuous cereals and summerfallow and lowest in the two rotations with broad-leaved crops (13% vs mean of 5%, LSD-test, P=0.05). The highest incidence of *C. sativus* occurred on wheat stubble when the previous crop was either flax, summerfallow, spring wheat, or chem-

fallow (ranging from lowest to highest, 5-20%) and lowest with either pea or winter wheat (0-1%). Sporulation of *C.sativus* is usually highest on cereal residues and lower on oilseed and pulse crops, although it can sporulate on both flax and pea.

In field pea, *Mycosphaerella pinodes* (Berk & Blox.) was the only foliar pathogen at the site and fusarium root rot [*Fusarium* spp.] was the dominant root disease. Differences in foliar disease incidence and severity among tillage treatments were generally small, so only the final severity data are presented (Table 1). Conventional tillage resulted in a small decrease in severity compared to reduced tillage in both 1993 and 1994. Similarly, for root rot incidence and severity, there was no consistent differences among the tillage treatments, so only the final severity data are presented. In 1994, there was a substantial difference among tillage treatments in one of three ratings (not shown), but by the end of the season, this difference had disappeared (Table 1). Pea yields were similar among tillage treatments in 1991- 1993 (Table 1 for 1992 and 1993). In 1991 the yield was 2700 kg ha $^{-1}$ in zero, 2800 kg ha $^{-1}$ in minimum and 2600 kg ha $^{-1}$ in conventional tillage. In 1994, pea yield with zero tillage was slightly greater. No other differences were noted.

3c. Observations: Rotation Cycle Three, 1995-1998

Reduced tillage practices increased foliar disease severity in wheat in 1995 and 1996, but in the remaining two years of the study tillage practice had no effect on leaf spot severity (Table 4). Tillage practice also had no effect on root disease severity or yield in most years. Foliar and root disease severity on wheat was similar in all rotations. Wheat yields increased with rotations using broad-leaved crops as compared to summerfallow-cereal systems in two years. There were no interactions between tillage practice and rotation.

Examination of the individual crops grown in sequence showed that foliar and root disease severity were greater in winter wheat than spring wheat (Table 5). Yields of winter wheat were lower than spring wheat in the summerfallow-cereal rotation but higher than spring wheat in the rotations using broad-leaved crops (except in 1998). Among the spring wheat treatments, yield was highest after either summerfallow or pea in three of four years (1995-1997); foliar disease severity was lowest following summerfallow in 1995-1997 and pea in 1996 and 1997. Summerfallow or pea had no effect on root severity.

The precipitation and growing degree days, which were measured on site, were variable from year to year. The growing season precipitation (May to August) was below the 82-year average (225mm) with only 131 mm in 1996 and 124 mm in 1997; precipitation was above the average in 1995 and 1998 with 297mm and 356 mm, respectively. Warmer than average temperatures resulted in the growing degree days from April to September ranging from a low of 1841 (in 1995) to a high of 2840 (in 1997) compared to the long-term mean of 1659. Warm and dry conditions in 1997 reduced the foliar disease severity more than in other years of the study whereas the cool, moist conditions in 1995 increased the severity of root disease (Table 4). In some years, certain diseases or causal agents were associated with losses in wheat yield: i) $\text{Yield}_{1995} = -310_{\text{common root rot severity}} + 158_{\text{leaf spot severity}} + 2225$, $R^2 = 0.13$, $P < 0.05$, ii) $\text{Yield}_{1998} = -121_{P.\ tritici\text{-}repentis} - 66_{S.\ nodorum} - 481_{C.\ sativus} + 4318$, $R^2 = 0.25$, $P < 0.05$, iii)

Yield $_{1997}$ = -197 $_{S.\ tritici}$ + 1140, R^2 = 0.26, $P < 0.05$, and iv) Yield $_{1998}$ = -3014 $_{C.\ sativus}$ - 62 $_{S.\ tritici}$ + 2724, R^2 0.29, $P <$ 0.001.

The prevalence of leaf-spotting fungi on wheat during the growing season was not affected by tillage practice except for the incidence of *S. nodorum* increasing with reduced tillage in 1997 (Table 6). In 1995, the incidence of *C. sativus* from roots was lower with reduced tillage whereas the incidence of *Fusarium* spp. increased with reduced tillage in 1996 and 1997. The majority of subsampled *Fusarium* spp. were pathogenic to wheat (57%) and were identified as *F. equisetti, F. culmorum, F. acuminatum*, and *F. graminum*. The pathogen *G. graminis* var. *tritici* which causes take-all of wheat was only present in 1995 and 1996; reduced tillage decreased the incidence of this pathogen in 1995 (Table 3).

The rotation using pea-spring wheat-flax-winter wheat had the lowest incidence of *S. tritici* (in 1997 and 1998), *S. nodorum* (in 1996 and 1997),and *C. sativus* (from the root disease complex in 1996) compared to the summerfallow-cereal rotation (Table 3). In 1995, this same diverse broad-leaved crop rotation had a higher incidence of *Fusarium* spp. The incidence of *G. graminis* var *tritici* was not influenced by the rotations.

In field pea, *Mycosphaerella pinodes* (Berk & Blox.) was the dominant foliar pathogen and fusarium root rot (*Fusarium* spp.) was the dominant root disease at the site each year. There were no substantial differences in incidence or severity of either disease among tillage treatments at any date, so only the final severity assessments are presented (Table 1). In 1995, mycosphaerella blight severity was low throughout the season, and blight severity under zero-tillage was slightly higher than for the other two tillage regimes. In 1996, blight severity was low to moderate, and there were no differences among tillage systems. There were no differences in fusarium root rot severity or yield among tillage treatments in any year.

3d. Discussion

At the completion of the second and third rotation cycles in this long-term study, reduced tillage practices did not significantly increase the severity of foliar diseases in wheat to result in yield losses, nor did it increase the incidence of the fungal species causing leaf spotting during the growing season. During the first cycle of the study, leaf spot severities were slightly higher with reduced tillage in one of four years and in none of the years during the second cycle. During the third rotation cycle, leaf spot severity slightly increased with reduced tillage in two of the four years, but yield was only reduced in one of those years. Therefore, reduced tillage practices had little impact on the disease severity or yield loss.

Over all years of the study, tillage had a greater impact on the root diseases of wheat and their pathogen populations than on the foliar diseases. In years when the pathogens were present, *C. sativus* and *G. graminis* var. *tritici* were significantly less prevalent and disease was less severe with reduced tillage practices in 6 of 11 years and 3 of 4 years, respectively. The incidence of *Fusarium* spp. increased with reduced tillage in only 2 of the 7 years it was isolated from Cycle 2 and Cycle 3, but this same trend was observed more frequently in another study conducted at the same site. Despite the change in the relative importance of the root pathogens, the expression of

symptoms (i.e. disease severity) remained at similar levels. Disease severity of common root rot is influenced by temperature-related parameters and the extension of lesions along the subcrown internode often increases during the growing season, as the hosts mature and the seasonal temperatures increase, whereas the incidence of infected plants is influenced by moisture-related parameters. Although severity is dependent upon incidence, the reverse is not true. Hence, incidence maybe a more appropriate measure of disease control.

The most diverse crop rotation using both broad-leaved and cereal crops (i.e. pea-spring wheat-flax-winter wheat) provided the greatest advantage to gains in yield of wheat whereas the summerfallow-cereal based system produced the lowest yields in 5 of 7 years during both Cycle 2 and Cycle 3. Oddly, in our study, there were few, consistent differences in disease severity or the prevalence of most pathogens between these rotations during the three cycles. For example, foliar disease severity was lower with the most diverse rotation as compared to summerfallow-cereals in only two years (1990 and 1992); root disease severity increased in 1987 and 1992, but decreased in 1989 and 1993 with the most diverse rotation. In 3 of 7 years, the incidence of *Fusarium* species from wheat roots was higher in the rotations using the broad-leaved crops whereas *C. sativus* decreased in those situations. Upon closer examination, it appeared that it was certain cropping sequences within a rotation that influenced disease. *Fusarium* species were more abundant in wheat following either another cereal or flax. Low foliar disease severities were observed on spring wheat after summerfallow or after pea in 10 of 11 years. The crop sequence that increased foliar disease severity was spring wheat after spring wheat in the summerfallow-cereal crop rotation (3 of 4 years in Cycle 3).

The results for field pea in Cycle 3 were similar to those from Cycles 1 and 2. *Mycosphaerella pinodes* (Berk & Blox.) was the dominant, and generally the only, foliar pathogen at the site; fusarium root rot [*Fusarium* spp.] was the dominant root disease, although *Pythium* spp. would have been difficult to detect in these assessments. Tillage system did not have a substantial impact on the incidence (data not shown) or severity of foliar or root diseases of field pea in Cycle 3 or in previous cycles. Previous studies had shown that survival of the *M. pinodes* is reduced when infected residue is buried, so this was an unexpected result for mycosphaerelia blight. We conclude that tillage regime had little or no impact on mycosphaerella blight and fusarium root rot of field pea grown in 4-yr rotations with cereals or flax. However, the cropping history of the study area prior to the trial was primarily cereals and summerfallow in a relatively weed-free environment, with no prior history of pea production. Field pea was grown on only 1/12 of the plot area in any year, and this limited area was reseeded (using high quality, certified seed) to field pea only every fourth year. Given these constraints to disease introduction and development, it is not surprising that the community of pathogens on field pea at this site was extremely simple. These results also illustrate how optimum management can limit the introduction and spread of diseases on crops such as field pea. The results of this longer-term study supports observations from a 4-yr study of more diverse cropping rotations at the same site. The study of diverse cropping rotations showed that tillage system did not affect foliar or root rot incidence or severity in field pea or lentil grown in 4-yr rotations.

The implications of this research are significant for Saskatchewan. For wheat and pea grown in south-

eastern Saskatchewan, tillage method should not increase the common foliar diseases nor the root diseases of pea sufficiently to result in yield reductions. To reduce foliar diseases of wheat, it should be grown after either summerfallow, chem-fallow, or pea. Reduced tillage practices may be used to reduce the levels of common root rot and take-all in wheat. Combining reduced tillage in cereals with increasing broad-leaved crop diversity will also lower the risk of most diseases and increase yield. However, it is important to note that the relative proportion of the root pathogen species in the soil and on the crop residue changes with these practices. *Fusarium* species on wheat increase with reduced tillage and with the use of broad-leaved crops, particularly flax. Flax is also a host for many *Fusarium* species. The higher levels of inoculum may present an increased risk of fusarium-related diseases such as prematurity blight and fusarium head blight, if the environmental conditions favour their development. At the site in this study, the environmental conditions conducive to the progression of these diseases were never observed, although the pathogens were present and infected the wheat plants. Producers in areas where the chance of these fusarium-related diseases are higher, may wish to consider more conventional tillage practices and not growing wheat after wheat or wheat after flax.

3e. Conclusions

In conclusion, this 12 year project has demonstrated that new or unusual disease problems did not develop with the long-term use of reduced tillage in south-eastern Saskatchewan. Typically, foliar leaf spot diseases and common root rot occurred every year, while occasionally take-all appeared in some years depending on environmental conditions. These plant diseases were associated with yield losses in 4 of 7 years. Changing from conventional tillage systems to reduced tillage systems should not create management problems, such as losses in yield, from the leaf spot diseases of wheat. Cereal leaf spots may increase with reduced tillage practices in some years, but more often the increased level of disease did not translate into yield losses. Reduced tillage systems slightly decreased the overall severity of the root diseases and changed the relative importance of the pathogen species in the complex. It reduced the populations of *C. sativus* and increased, by an equal proportion, the populations of *Fusarium* species, most which were pathogenic to wheat. The higher levels of *Fusarium* may present an increased risk of fusarium-related diseases such as prematurity blight or head blight in areas where the environmental conditions allow the disease to develop. Although take-all was a sporadic disease, the use of zero tillage may help to limit the occurrence of this disease problem.

Crop diversification should help improve crop stability by lowering the risks associated with building reserves of pathogen inoculum that may increase uncontrollably in unpredictable environments. Although the environment has a larger influence on the disease severity within a crop than either tillage or rotation, cropping sequence can modify some disease levels. Rotations using three years of continuous wheat followed by either a fallow period or a non-cereal crop increased cereal leaf spot disease by not providing a long enough break period to reduce pathogen inoculum. Diversity in crop rotations, such as alternating years between a cereal and non-cereal crop did improve wheat yield. The greatest impact from rotation for disease management came from using

particular cropping sequences, such as growing wheat after summerfallow, chem-fallow, or pea to reduce foliar leaf spots. In areas where there is a higher risk of developing fusarium-related diseases, wheat should not be grown after flax, spring wheat, or winter wheat as these cropping sequences raise the level of inoculum of *Fusarium*. If these types of disease are not a concern for an area, then based on the crops used in this study, the most successful rotation would use a non-cereal crop such as pea or flax alternating between years with a cereal crop, such as either spring or winter wheat.

3 f. Communication of Results

The results of this research have been presented to the public and scientific community in the following ways:

i) October 1997: Interviewed for article called "Disease Management in Direct Seeding" by Janet Kanter for an upcoming issue of Top Crop Manager magazine.

ii) November 1997: Abstract published: Gossen, B.D., K.L. Bailey, and G.P. Lafond. 1997. Impact of tillage management on disease severity in field pea in a four year rotation. Can. J. Plant Pathol. 19:324-325.

iii) November 1997: Presentation at the SSCA Agrologist Workshop in Saskatoon called Plant Diseases: To control or not to control by Karen L. Bailey.

iv) November 1998: Anderson, K., K.L. Bailey, B.D. Gossen, and G.P. Lafond. 1999. Impact of crop management system on disease severity of wheat and field pea 1995-1997. Can J. Plant Pathol. 21: 193 (Abstr.). Oral presentation at the Saskatchewan Regional Meeting of Canadian Phytopathological Society.

v) January 1999: G.P Lafond, Karen L. Bailey, Doug. A. Derksen, and Robert.P. Zentner. 1999. Twelve years of a tillage x crop rotation study: Major findings and new opportunities. Page 12-22 in Proceeding of the Manitoba-North Dakota Zero Till Association, January 25-27.

vi) December 1999: Bailey, K.L., B.D. Gossen, and G.P. Lafond. 2000. Effect of tillage systems and crop rotation on root and foliar diseases of wheat and pea in Saskatchewan: Rotation Cycle 2, 1991-1994. Can J. Plant Sci. (manuscript in review)

vii) December 1999: Bailey, K.L., B.D. Gossen, and G.P. Lafond. 2000. Effect of tillage systems and crop rotation on root and foliar diseases of wheat and pea in Saskatchewan: Rotation Cycle 3, 1995-1998. Can J. Plant Sci. (manuscript in review)

viii) December 1999: Bailey, K.L., B.D. Gossen, G.P. Lafond, D.A. Derksen, A.M. Johnston. 2000. Factsheet: Impact of tillage on plant diseases in Saskatchewan. AAFC and ADF website (factsheet in review).

ix) January 2000: Bailey, K.L., B.D. Gossen, G.P.Lafond, P.R. Watson, and D.A. Derksen. 2000. Impact of tillage, rotation, and environment on diseases of wheat and pea in south-eastern Saskatchewan. Can J. Plant Sci. (manuscript in preparation). Oral presentation to the Joint meeting of Canadian Phytopathological Society and the Northwestern Division of the American Phytopathological Society, June, 2000, Victoria, BC.

Personnel

1997-1998

Karyn Sutherland was hired from April 1, 1997 to September 2, 1997 to work 1/3 of her time on this project which was previously funded from 1992-1996 by the Canada-Saskatchewan Green Plan Agreement.

Carolyn Wilson and Ryan Beaujot were hired on a part-time basis ($11.08/hr for 12 hours per week) from September through December in 1997 to conduct the disease ratings and the laboratory analysis of the fungal species infecting the cereal tissues.

1998-1999

Carolyn Wilson and Ryan Beaujot were hired on a part-time basis ($11.08/hr for 12 hours per week) from January through April in 1998 to conduct the disease ratings, laboratory analysis of the fungal species infecting the cereal tissues, and data entry.

Carloyn Wilson was hired as a summer student from May 5 1998 to August 28, 1998 .

Mike Gusta was hired on a part-time basis (11.08/hr for maximum of 12 hr/wk) for laboratory plating, August 31-December 31, 1998.

Carolyn Wilson was hired on a part-time basis (11.08/hr for maximum of 12 hr/wk) for laboratory plating, November 2, 1998- April 30, 1999.

Christa Anderson was hired as a part-time technician ($3125/month) from April 1999 to January 1, 2000.

Mark Taylor and Lane Gelhorn were hired on a part-time basis (11.08/hr for maximum of 12 hr/wk) for data collation, September 3 - December 31, 1999.

Services for specialized statistical analyses were contracted ($10,000) from Drs. Doug Derksen and Paul Watson , AAFC, Brandon, MB.

Equipment

None.

Project Developed Materials

Gossen, B.D., K.L. Bailey, and G.P. Lafond. 1997. Impact of tillage management on disease severity in field pea in a four year rotation. Can. J. Plant Pathol. 19:324-325.

Anderson, K., K.L. Bailey, B.D. Gossen, and G.P. Lafond. 1999. Impact of crop management system on disease severity of wheat and field pea 1995-1997. Can J. Plant Pathol. 21: 193 (Abstr.)

Lafond,G.P., Karen L. Bailey, Doug. A. Derksen, and Robert.P. Zentner. 1999. Twelve years of a tillage x crop rotation study: Major findings and new opportunities. Page 12-22 in Proceeding of the Manitoba-North Dakota Zero Till Association, January 25-27.

Bailey, K.L., B.D. Gossen, and G.P. Lafond. 2000. Effect of tillage systems and crop rotation on root and foliar diseases of wheat and pea in Saskatchewan: Rotation Cycle 2, 1991-1994. Can J. Plant Sci. (manuscript in review, draft attached)

Bailey, K.L., B.D. Gossen, and G.P. Lafond. 2000. Effect of tillage systems and crop rotation on root and foliar diseases of wheat and pea in Saskatchewan: Rotation Cycle 3, 1995-1998. Can J. Plant Sci. (manuscript in review; draft attached)

Bailey, K.L., B.D. Gossen, G.P.Lafond, P.R. Watson, and D.A. Derksen. 2000. Impact of tillage, rotation, and environment on diseases of wheat and pea in south-eastern Saskatchewan. Can J. Plant Sci. (manuscript in preparation)

Bailey, K.L., B.D. Gossen, G.P. Lafond, D.A. Derksen, A.M. Johnston. 2000. Factsheet: Impact of tillage on plant diseases in Saskatchewan. AAFC and ADF website (draft attached).

Project Photos

Slides taken of causal agents for publication purposes.

Acknowledgement

ADF was acknowledged for supporting this tillage and rotation research in presentations given at a Saskatchewan Soil Conservation Association Inc. Workshop to approximately 180 agronomists and producers in Saskatoon, to 80 researchers from Alberta and Saskatchewan at the Joint meeting of the PPSA and CPS, to approximately 500 producers and researchers in the prairie provinces and North Dakota at the ManDak 99 meetings, to CIMMYT wheat breeders in Mexico, and to the Canadian Phytopathological Society and American Phytopathological Society Joint Meeting, June 2000. It was also acknowledged in three scientific manuscripts and one factsheet.

Expense Statement

Final statement attached. The total expenditures for the project were on budget however the allocation of the expenditures was different than originally projected in the proposal. Initially, it was projected to use $1,000 for travel and $2,000 for rental. When the proposal was submitted, AAFC did not have adequate insurance coverage for the contracted employees to drive government vehicles. This policy was changed part way into the first year and the employees were then able to drive the government vehicles thus eliminating the need for further rentals. The rental fee of $407.75 was for the use of a growth cabinet to grow plants to confirm pathogenicity of fusarium isolates. In addition, the employees hired during this study, expressed a desire to travel to the site and return to Saskatoon without staying overnight thus greatly reducing the projected travel expenses. In an attempt to keep project expenses at a minimum, no material and supplies budget was originally projected, assuming that most costs could be covered by AAFC. Due to the processing of a large number of field samples in the laboratory, and the extensive number of publication materials developed with this project, it was necessary to re-allocate project resources to help cover the costs with materials and supplies.

Table 1. Effect of tillage and crop rotation on foliar and root disease severity and yield of wheat[¶] and field pea at Indian Head, SK from 1992-1994.

Variable or practice [‡]	1992	1993	1994
	------ Tillage, Wheat ------		
Foliar severity			
Zero	7.9 a [†]	7.4 a	7.9 a
Minimum	7.6 a	7.4 a	7.7 a
Conventional	7.6 a	7.3 a	7.7 a
Root severity			
Zero	1.0 a	0.7 a	1.2 a
Minimum	1.1 a	0.8 a	1.2 a
Conventional	1.2 a	0.8 a	1.4 a
Yield ('000 kg ha^{-1})			
Zero	3.9 a	1.8 a	3.2 a
Minimum	4.1 a	1.9 a	3.2 a
Conventional	3.9 a	2.0 a	3.2 a
	----Rotation, Wheat ----		
Foliar severity			
Sf-Sw-Sw-Ww	7.7 a	7.3 a	7.8 a
Sw-Sw-Flax-Ww	7.9 a	7.6 a	7.7 a
Pea-Sw-Flax-Ww	7.1 b	7.3 a	7.6 a
Root severity			
Sf-Sw-Sw-Ww	1.0 a	0.7 ab	1.2 a
Sw-Sw-Flax-Ww	1.0 a	0.8 a	1.3 a
Pea-Sw-Flax-Ww	1.3 b	0.5 b	1.2 a
Yield ('000 kg ha^{-1})			
Sf-Sw-Sw-Ww	4.1 a	1.6 a	3.0 a
Sw-Sw-Flax-Ww	3.6 b	1.9 a	3.2 b
Pea-Sw-Flax-Ww	4.1 a	2.5 b	3.5 c
	------Tillage, Pea------		
Foliar severity			
Zero	nd	5.2 b	5.5 b
Minimum	nd	5.2 b	5.8 c
Conventional	nd	4.8 a	5.2 a
Root severity			
Zero	nd	1.5 a	1.2 a
Minimum	nd	1.6 a	1.0 a
Conventional	nd	1.7 a	1.0 a
Yield ('000 kg ha^{-1})			
Zero	2.8 a	2.7 a	2.4 b
Minimum	2.4 a	2.6 a	2.2 a
Conventional	2.4 a	2.6 a	2.2 a

† For each variable assessed, values in columns followed by the same letter are not significantly different at $P \leq 0.05$ based on Duncan's Multiple Range test; nd = not done.
‡ Foliar severity, 0-11 scale; Root severity, 0-3 scale; Sf, summerfallow; Sw, spring wheat; Ww, winter wheat.
¶ Mean of spring and winter wheat crops.

Table 2. Impact of foliar and root disease severity and yield on spring and winter wheat treatments in three crop rotations at Indian Head, SK from 1992-1994.

Rotation ¥	Wheat sequence	Foliar severity (0-11 scale)			Root severity (0-3 scale)			Yield ('000 kg ha^{-1})		
		1992	1993	1994	1992	1993	1994	1992	1993	1994
Sf<Sw_1<Sw_2<Ww	Sw_1	3.5a	6.5a	7.6a	1.4a	0.2ab	1.2ab	4.1c	2.0b	2.9b
	Sw_2	3.9a	7.1b	8.1a	1.0a	0.2ab	1.5b	3.7bc	1.3a	2.6a
	Ww	7.7b	8.2c	7.8a	3.0b	0.2ab	0.7a	4.4d	1.5a	3.7c
Sw_1<Sw_2<Flax<Ww	Sw_1	4.2a	7.4b	7.7a	1.5a	0.2ab	1.6b	3.2a	1.3a	2.8b
	Sw_2	4.3a	7.0b	7.5a	1.3a	0.3a	1.6b	3.5b	1.4a	2.8b
	Ww	7.1b	8.3c	7.8a	nd	0.0b	0.8a	4.5d	2.8c	4.0d
Pea<Sw<Flax<Ww	Sw	3.6a	6.2a	7.7a	1.1a	0.2ab	1.3ab	3.8bc	2.1b	2.8b
	Ww	6.8b	8.4c	7.6a	1.0a	0.0b	1.1ab	4.6d	2.8c	4.1d

† For each year, values in columns followed by the same letter are not significantly different at P=0.05 based on Duncan's Multiple Range test; nd, no data

¥ Sf, summerfallow; Sw, spring wheat; Ww, winter wheat

Table 3. Impact of crop management on the prevalence of causal agents of foliar and root disease on spring and winter wheat at Indian Head, SK from 1992-1994.

Year	Crop management	Foliar Disease Complex ¶				Root disease complex ¶		
		%Ptr	*%St*	*%Sn*	*%Cs*	*%Cs*	*%Fus*	*%Ggt*
				---Tillage---				
1992	Zero	nd	57.5a†	41.9a	0.6a	10a	80a	nd
	Minimum	nd	51.2a	48.4a	0.4a	10a	80a	nd
	Conventional	nd	54.3a	45.2a	0.5a	30b	70a	nd
1993	Zero	14.9a	57.4a	27.3a	0.4a	20a	50a	nd
	Minimum	13.4a	58.9a	27.2a	0.5a	20a	40a	nd
	Conventional	9.4a	58.7a	31.6a	0.3a	40b	40a	nd
1994	Zero	24.7a	41.1a	34.2a	nd	20a	60a	5a
	Minimum	25.5a	31.1a	43.4a	nd	20a	60a	14b
	Conventional	22.0a	40.1a	37.9a	nd	20a	50a	11ab
				---Rotation---				
1992	Sf-Sw-Sw-Ww	nd	56.8a	42.6a	0.6a	30a	70a	nd
	Sw-Sw-Flax-Ww	nd	54.1a	45.5a	0.4a	20a	80b	nd
	Pea-Sw-Flax-Ww	nd	48.8a	50.9a	0.3a	20a	80b	nd
1993	Sf-Sw-Sw-Ww	12.2a	61.7b	25.7a	0.4a	30a	40a	nd
	Sw-Sw-Flax-Ww	11.5a	56.1ab	32.2a	0.2a	20a	40a	nd
	Pea-Sw-Flax-Ww	14.6a	56.3a	28.5a	0.6a	30a	50a	nd
1994	Sf-Sw-Sw-Ww	21.5a	38.5a	40.0a	nd	30b	50a	12a
	Sw-Sw-Flax-Ww	23.5a	35.2a	41.3a	nd	10a	50a	12a
	Pea-Sw-Flax-Ww	23.5a	39.3a	37.2a	nd	20ab	70b	5a

† In each year, values in columns followed by the same letter are not significantly different at $P \leq 0.05$ using a LSD test; nd, no data.

¶ *Ptr, Pyrenphora tritici-repentis*; *St, Septoria tritici*; *Sn, Stagnospora nodorum*; *Cs, Cochliobolus sativus*; *Fus, Fusarium* spp.; *Ggt, Gaeumannomyces graminis* var. *tritici*.

¥ Sf, summerfallow; Sw, spring, wheat; Ww, winter wheat; nd, no data

Table 4. Effect of tillage and crop rotation on foliar and root disease severity and yield of wheat [1] and field pea at Indian Head, SK from 1995-1998.

Variable or practice ¥	1995	1996	1997	1998
		------Tillage, Wheat------		
Foliar severity				
Zero	8.4 b †	10.5 b	6.0 a	10.6 a
Minimum	7.9 a	10.6 b	5.8 a	10.6 a
Conventional	7.7 a	10.3 a	6.0 a	10.6 a
Root severity				
Zero	1.7 a	1.1 a	0.9 a	1.2 a
Minimum	1.7 a	1.1 a	0.9 a	1.1 a
Conventional	1.7 a	1.3 a	0.8 a	1.4 a
Yield (000's kg ha^{-1})				
Zero	2.7 a	3.3 a	1.4 a	1.8 a
Minimum	2.7 a	3.3 a	1.4 a	1.9 a
Conventional	3.0 b	3.4 a	1.3 a	2.0 a
		------ Rotation, Wheat------		
Foliar severity				
Sf-Sw-Sw-Ww	7.7 a	10.4 a	5.9 a	10.5 a
Sw-Sw-Flax-Ww	7.9 a	10.5 a	5.9 a	10.6 a
Pea-Sw-Flax-Ww	8.7 a	10.4 a	5.8 a	10.7 a
Root severity				
Sf-Sw-Sw-Ww	1.6 a	1.2 a	0.8 a	1.1 a
Sw-Sw-Flax-Ww	1.7 a	1.2 a	0.9 a	1.1 a
Pea-Sw-Flax-Ww	1.9 a	1.1 a	0.8 a	1.3 a
Yield (000's kg ha^{-1})				
Sf-Sw-Sw-Ww	2.7 a	2.9 a	1.5 a	1.7 a
Sw-Sw-Flax-Ww	2.7 a	3.4 b	1.3 a	2.0 a
Pea-Sw-Flax-Ww	3.1 b	3.8 c	1.5 a	1.9 a
		-----Tillage, Pea-----		
Foliar severity				
Zero	2.5 b	2.6 a	4.0 a	5.3 a
Minimum	1.8 a	2.6 a	4.0 a	5.0 a
Conventional	1.7 a	2.7 a	4.0 a	5.1 a
Root severity				
Zero	1.2 a	1.5 a	1.5 a	0.8 a
Minimum	1.3 a	1.3 a	1.3 a	0.9 a
Conventional	1.4 a	1.3 a	1.3 a	0.8 a
Yield (000's kg ha^{-1})				
Zero	2.6 a	3.3 a	1.7 a	3.5 a
Minimum	2.8 a	3.7 a	1.5 a	3.0 a
Conventional	2.6 a	3.4 a	1.3 a	2.8 a

† For each variable assessed, values in columns followed by the same letter are not significantly different at $P \leq 0.05$ based on Duncan's Multiple Range test; nd = not done.
¥ Foliar severity, 0-11 scale; Root severity, 0-3 scale; Sf, summerfallow; Sw, spring wheat; Ww, winter wheat.
¶ Mean of spring and winter wheat crops.

Table 5. Impact of foliar and root disease severity and yield on spring and winter wheat treatments in three crop rotations at Indian Head, SK from 1995-1998.

Rotation ¥	Wheat sequence	Foliar severity (0-11 scale) 1995	1996	1997	1998	Root Severity (0-3 scale) 1995	1996	1997	1998	Yield (000's kg ha^{-1}) 1995	1996	1997	1998
Sf<Sw_1<Sw_2<Ww													
	Sw_1 5.7a	9.1a	4.3a	10.1a	1.2d	1.1a	0.7a	0.5a	3.2c	3.3b	2.0c	2.1bcd	
	Sw_2 6.5b	10.6d	6.3d	10.4a	1.4cd	1.1a	0.8a	0.5a	2.6b	2.9a	1.2a	2.3cd	
	Ww	10.9c	11.0e	7.3e	11.0b	2.3a	1.4a	nd	2.1b	2.4a	2.7a	1.2a	0.8a
Sw_1<Sw_2<Flax<Ww													
	Sw_1 6.3b	9.9b	5.9cd	10.3a	1.6c	1.4a	0.9a	0.7a	2.3a	2.7a	1.0a	2.3cd	
	Sw_2 6.5b	10.3c	5.6bc	10.5a	1.4cd	1.2a	0.9a	0.7a	2.3a	2.7a	1.2a	2.1bcd	
	Ww	10.9c	11.0e	6.4d	11.0b	1.9b	1.1a	nd	1.8b	3.4c	4.0c	1.6b	1.7b
Pea<Sw<Flax<Ww													
	Sw	6.2b	9.2a	5.0b	10.4a	1.6c	1.0a	0.8a	0.7a	2.7b	3.3b	1.4b	2.2a
	Ww	11.0c	11.0e	6.6d	11.0b	2.2ab	1.2a	nd	1.9b	3.5c	4.1c	1.5b	1.6b

† For each year, values in columns followed by the same letter are not significantly different at P=0.05 based on Duncan's Multiple Range test.

¥ Sf, summerfallow; Sw, spring, wheat; Ww, winter wheat

Table 6. Impact of crop management on the prevalence of causal agents of foliar and root disease on spring and winter wheat at Indian Head, SK from 1995-1998.

Year	Crop management	Foliar Disease Complex ¶				Root disease complex ¶		
		%*Ptr*	%*St*	%*Sn*	%*Cs*	%*Cs*	%*Fus*	%*Ggt*
				—Tillage—				
1995	Zero	nd ¥	nd	nd	nd	49a †	70a	9a
	Minimum	nd	nd	nd	nd	48a	68a	12a
	Conventional	nd	nd	nd	nd	66b	59a	19b
1996	Zero	11a	56a	32a	1a	59a	83b	50a
	Minimum	15a	59a	23a	3ab	56a	77ab	48a
	Conventional	18a	61a	17a	4b	66a	76a	51a
1997	Zero	16a	45a	35b	4a	23a	28b	nd
	Minimum	13a	50a	34b	3a	19a	28b	nd
	Conventional	19a	55a	22a	4a	25a	22a	nd
1998	Zero	22a	54a	23a	1a	11a	27a	nd
	Minimum	21a	54a	24a	1a	11a	28a	nd
	Conventional	27a	44a	28a	1a	11a	22a	nd
				—Rotation—				
1995	Sf-Sw-Sw-Ww	nd	nd	nd	nd	60a	60a	13a
	Sw-Sw-Flax-Ww	nd	nd	nd	nd	54a	65a	13a
	Pea-Sw-Flax-Ww	nd	nd	nd	nd	47a	75b	10a
1996	Sf-Sw-Sw-Ww	13a	56a	28b	3a	68b	79a	49a
	Sw-Sw-Flax-Ww	17a	57a	24ab	2a	57a	78a	52a
	Pea-Sw-Flax-Ww	12a	69a	17a	2a	54a	80a	47a
1997	Sf-Sw-Sw-Ww	15a	54b	27b	4b	21a	27a	nd
	Sw-Sw-Flax-Ww	15a	50a	32b	3a	22a	25a	nd
	Pea-Sw-Flax-Ww	24a	50a	22a	4b	24a	29a	nd
1998	Sf-Sw-Sw-Ww	22a	53b	24a	1a	11a	25a	nd
	Sw-Sw-Flax-Ww	23a	51ab	25a	1a	11a	25a	nd
	Pea-Sw-Flax-Ww	26a	47a	26a	1a	13a	26a	nd

† In each year, values in columns followed by the same letter are not significantly different at $P \leq 0.05$ using a LSD test; nd, no data.

¶ *Ptr*, *Pyrenphora tritici-repentis*; *St*, *Septoria tritici*; *Sn*, *Stagnospora nodorum*; *Cs*, *Cochliobolus sativus*; *Fus*, *Fusarium* spp.; *Ggt*, *Gaeumannomyces graminis* var. *tritici*.

¥ Sf, summerfallow; Sw, spring, wheat; Ww, winter wheat; nd, no data

DRAFT

Impact of tillage on plant diseases in Saskatchewan

K.L. Bailey [1], B.D. Gossen [1],G.P Lafond [2] D.A. Derksen [3], and A.M. Johnston [4]

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[2] Agriculture & Agri-Food Canada, Indian Head, SK,
[3] Agriculture & Agri-Food Canada, Brandon, MB
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Problem

Agronomic practices on the Canadian prairies are moving away from a reliance on cultivation. In the 1990's, there was a 22% decline in summerfallow acreage and a 117% increase in the area managed by no-till in Saskatchewan. These practices increase the amount of residue left on the soil surface and may lead to increases in crop disease severity. Residue-borne pathogens utilize crop residue as an overwintering habitat and also as a nutritional source. Reduced tillage leaves greater quantities of residue on the soil surface, where it takes longer to decompose. It also increases soil moisture and organic matter and decreases soil temperature, which can change the status of microbial populations in soil. This study monitored the long-term dynamics (1987-1998) of plant diseases on cereal and pea grown under conventional and zero tillage on a heavy clay, thin black soil at Indian Head, SK.

Study Description

Tillage systems.

- Conventional tillage used fall tillage & banded N followed by spring tillage.
- Zero tillage used one pass seeding with seed & side-banded N.

Crop sequences.

- Summerfallow, spring wheat, spring wheat, winter wheat
- spring wheat, spring wheat, flax, winter wheat
- pea, spring wheat, flax, winter wheat

Study Conclusions

- Foliar diseases of spring wheat, winter wheat, and pea were not substantially affected by tillage system.
- Zero tillage had an impact on root pathogens of wheat. Common root rot and take-all were less severe with zero tillage but *Fusarium* increased. Root pathogens of pea were not affected.
- Reduced tillage practices may increase the risk of fusarium head blight in wheat by 10%.

Applied Questions

What is the impact of reduced tillage on crops other than wheat and pea?

Each disease-crop combination responds differently and the impact is difficult to predict. On barley, scald increases under reduced tillage in Alberta and Saskatchewan, whereas other leaf spotting diseases, such as net blotch and spot blotch, do not increase. At Melfort, SK, the incidence of blackleg and sclerotinia stem rot of canola was not affected by tillage system and similarly the severity of ascochyta blight on lentil did not increase over a four year period with reduced tillage at Indian Head, SK.

What is the impact of reduced tillage on diseases in other parts of the province?

Environments conducive to disease development (i.e. warm, moist) may have increased losses due to plant diseases, but these will occur regardless of the tillage management system. In the Black and Grey soil zones of Saskatchewan, where conservation tillage practices challenge crop production with high crop residue levels, higher soil moisture conditions, and greater N fertilizer demand, plant diseases often cause crop losses, particularly from foliar diseases. A four year study at Melfort, SK showed that crops grown under zero tillage did not have higher levels of foliar diseases or require more fungicide inputs than under conventional tillage. Studies from the Brown soil zone in southwestern Saskatchewan also show that leaf spot disease severity is similar under both zero- and conventional tillage practices.

References

1. Bailey, KL, K Mortensen, & GP Lafond. 1992. Effects of tillage systems and crop rotations on root and foliar diseases of wheat, flax, and peas in Saskatchewan. Can. J. Plant Sci 72:583-591.
2. Bailey, K, AM Johnston, HR Kutcher, BD Gossen, & RAA Morrall. 2000. Managing crop losses from foliar diseases with fungicides, rotation, and tillage in the Saskatchewan parkland. Can. J. Plant Sci.(in press).
3. Bailey, KL, BD Gossen, DA Derksen, & PR Watson. 2000. Impact of agronomic practices and environment on diseases of wheat and lentil. Can J. Plant Sci. (in review)
4.Fernandez, MR, BG McConkey & RP Zentner. 1998. Tillage and summerfallow effects on leaf spot diseases of wheat in the semiarid Canadian Prairies. Can. J Plant Pathol 20:376-379.
5. Turkington, TK, GW Clayton, & PA Burnett. 1996.The influence of tillage and nitrogen fertilizer on barley foliar diseases. Can. J. Plant Pathol. 18: 491.

Major Findings

The severity of leaf spot diseases (tan spot and septoria leaf blotch complex) were similar under zero and conventional tillage in 8 of 11 years (Fig. 1). In the years when differences occurred, severity was slightly higher under zero tillage, but only reduced yield (by 10%) in one year. The severity of leaf spots was more closely associated with seasonal precipitation (Fig. 1& 2).

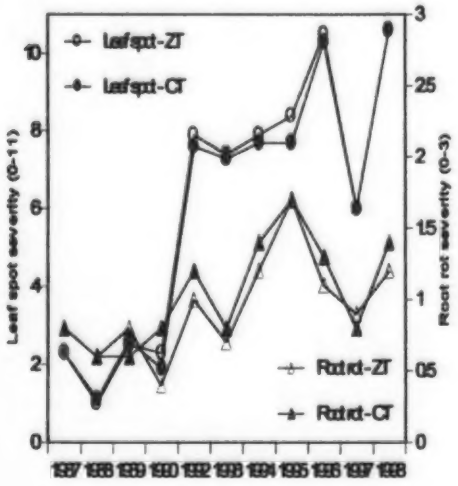

Figure 1. Severity of cereal diseases with tillage systems over 12 years at Indian head, SK.

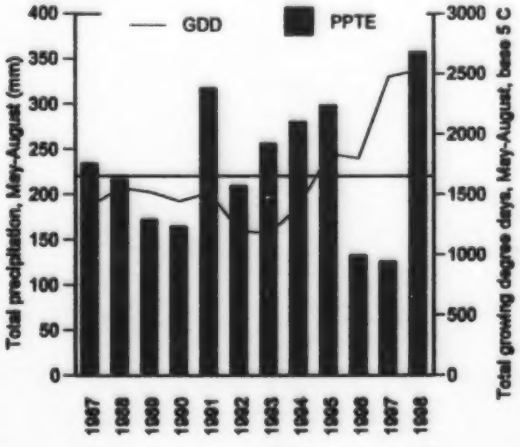

Figure 2. The weather patterns and long-term mean (solid black line) from 1987-1998, at Indian Head, S.

Root rot severity in wheat was slightly lower under zero tillage in most years (Fig. 1). Although the relative importance of the pathogens in the complex changed (Fig.3), the disease severity was only slightly affected. The fungal pathogens present in the roots were *Cochliobolus sativus* causing common root rot, *Gaeumannomyces graminis* causing take-all, and also *Fusarium* species associated with both common root rot and fusarium head blight. Reduced tillage practices may increase the risk of fusarium head blight in wheat but reduce the risk for common root rot and take-all.

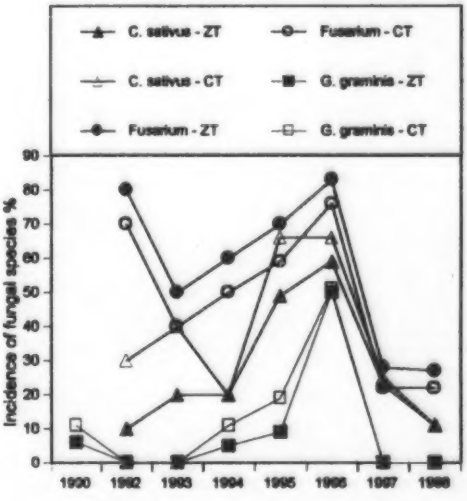

Figure 3. Changes in cereal root pathogens with tillage systems at Indian Head, SK.

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Effect of tillage systems and crop rotations on root and foliar diseases of wheat and pea in Saskatchewan: Rotation Cycle 2, 1991-1994.

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[1] Agriculture and Agri-Food Canada (AAFC), Research Centre, 107 Science Place, Saskatoon, Saskatchewan, S7N 0X2, [2] AAFC, Research Centre, Indian Head Experimental Farm, P.O. Box 760, Indian Head Saskatchewan, S4P 3A2

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Bailey, K.L., Gossen, B.D., Lafond, G.P. **Effect of tillage systems and crop rotations on root and foliar diseases of wheat and pea in Saskatchewan: Rotation Cycle 2, 1991-1994.** Can. J. Plant Sci xx: xx-xx. The long-term impact of tillage and rotation on wheat and pea diseases was examined in the second 4-yr rotation cycle from a study initiated in 1987. The trial consisted of three rotations (summerfallow-spring wheat-spring wheat-winter wheat; spring wheat-spring wheat-flax-winter wheat; field pea-spring wheat-flax-winter wheat) and three tillage practices (conventional, minimum, and zero). Disease severity and incidence of fungal species causing foliar leaf spot and root diseases were assessed from 1992-1994 (no ratings on wheat in 1991, or on pea in 1991-1992). Tillage practices did not have a substantial impact on the development of leaf spot diseases of wheat or root rot of field pea, or on the prevalence of these pathogens during the growing season. However, severity of mycosphaerella blight of pea was slightly reduced under conventional tillage. Reduced tillage resulted in a decrease in the incidence of *Cochliobolus sativus* and *Gaeumannomyces graminis* on wheat roots. Rotation had few effects on disease severity or prevalence, with a few notable exceptions. The incidence of *Fusarium* spp. on wheat roots increased in rotations that included broad-leaved crops. In contrast, cereal-oilseed-cereal-pulse rotation sequences reduced other root diseases and improved yields in wheat relative to the summerfallow-cereal systems. Tillage system and rotation had a larger impact on root pathogens of wheat than on foliar pathogens.

Key Words: rotation, tillage, root rot, leaf spot, wheat, pea

Abbreviations: Sw, spring wheat; Ww, winter wheat

Tillage and rotation practices vary widely across the Canadian prairies, but there has been an accelerating trend in the last 15 to 20 years to change from high-tillage, summerfallow-cereal based cropping systems to systems that combine reduced tillage with greater diversity in the crop rotation. As tillage was reduced, the severity of residue-borne pathogens was expected to increase; reduced tillage places greater quantities of residue on the soil surface, where they take longer to decompose, and so function as an inoculum source for a longer period (Bailey and Duczek 1996). Some studies have shown that over a 4-yr rotation cycle, tillage had little influence on foliar disease severity in wheat, although root disease severity often decreased with zero tillage (Bailey et al. 1992, Bailey et al. 2000, Bailey et al. In review). However, the long-term impact of tillage and its interaction with crop rotation in the region was not known. The objective of this study was to assess the longer-term impact of tillage and rotation on plant diseases in wheat and field pea by examining the dynamics of disease severity and populations of causal agents in the second 4-yr rotation cycle (1991-1994) of a study initiated in 1987 (Bailey et al. 1992).

METHODS AND MATERIALS

The study was conducted at the Agriculture and Agri-Food Canada Experimental Farm, Indian Head, SK. A detailed description of the agronomic methods used is described in Bailey et al. (1992). The tillage systems used were conventional (fall and spring tillage operations), minimum (one tillage operation in spring before seeding), and zero (no tillage). The rotations used were: 1) summerfallow-spring wheat (Sw)-Sw-winter wheat (Ww), 2) Sw -Sw-flax-Ww, and 3) field pea-Sw-flax-Ww. The first 4-yr cycle of the rotations ran from 1987-1990 and the second cycle from 1991-1994.

Visual disease severity on leaves and roots of spring wheat and winter wheat were estimated on 25 plants collected at random from a diagonal path across each plot between July 15 and August 10 in 1992-1994. Disease data were not collected in 1991. Root disease severity was estimated on the subcrown internode of each plant using a 0-3 scale, and the mean severity per plot was calculated (Stack 1992). Subcrown internode and crown pieces from each plant were washed for 1 hr under running tap water, then dried on absorbent paper. The root pieces were disinfested with 0.5% NaOCl for 3 min, rinsed twice with sterile distilled water, and then plated on minimal media (Tinline et al. 1960) containing 100 mg/L streptomycin sulfate and 50 mg/L vancomycin hydrochloride. The plates

were incubated at 20°C and 12 hr day. The percentage of plants infected with red *Fusarium* spp. (not identified to species level) and *Bipolaris sorokiniana* (Sacc.) Shoem., was recorded 7 to 9 days after plating. *Gaeumannomyces graminis* (Sacc.) von Arx & Olivier var. *tritici* Walker was isolated on semi-selective media (Juhnke et al. 1984) containing L-DOPA which produces a black pigmentation in the medium under the infected tissue. The lower 1-cm of the main stem was surface sterilized with 1% silver nitrate for 30 sec followed by two sterile distilled water rinses and blotted dry before plating. Plates were incubated at 20°C with 12 h daylight for 5 days.

Leaf spot severity on cereals was assessed using a 0-11 scale (McFadden 1991), where 1 represents slight disease in the lower plant canopy and 11 is severe disease in both the lower and upper plant canopies, based on a modified scale from Couture (1980). The flag leaf and penultimate leaf from 10 plants per plot were cut into 4-cm-long segments. These leaf pieces were washed in running water for 1 hr, disinfected for 1 min with 0.5% NaOCl, then plated on water agar containing 100 mg/L streptomycin sulfate and 50 mg/L vancomycin hydrochloride. The plates were incubated for 1 wk under a mixture of black light, black-blue light, and cool white fluorescent light. Fungal cultures were identified based on sporulation. Colonies of *Stagnospora nodorum* (Berk.) E. Castell. & Germano, *Septoria tritici* Roberge in Desmaz., *Pyrenophora tritici-repentis* (Died.) Drechs., and *Cochliobolus sativus* (Ito & Kurib.) Drechs. ex Dast. on each 4-cm segment were counted. The prevalence of a species was calculated by the number of colonies per unit area for that species, divided by the total colonies per unit area, and then expressed as a percentage.

In the spring of 1993, the wheat stubble residue of 10 plants grown in the previous year (growing season of 1992) were randomly collected from plots on May 19 to assess pathogen prevalence after an overwintering period. Each plant was divided into a below-ground sample for identification of root pathogens and an above-ground sample for identification of foliar pathogens from leaves and stems. The isolations methods used are described above.

In field pea, foliar and root rot incidence and severity were assessed on June 09 (seedling stage), July 14 (flowering) and August 10 (seed-filling) in 1993 and on July 14 (late-flower), August 10 (seed filling) and August 30 (maturity) in 1994. No assessments were made in 1991-92. On each sampling date, 25 plants were collected (5 plants per location, 5 locations per subplot) and rated for foliar and root disease severity. Foliar diseases were rated

using the Horsfall-Barrett scale (Horsfall and Barrett 1945). In addition, whole-plot foliar disease ratings were made at flowering and seed filling. Root rot was assessed using a 0-3 scale, where 1 represents 1-25% of the tap root diameter rotted, and 3 represents > 50% rotted (modified from Hwang et al. 1994). For all diseases, pathogens were identified based on symptoms and identification was confirmed by occasional plating of surface-disinfested samples onto PDA.

Differences in the pathogen populations and disease severity in each year were compared using analysis of variance, with *a priori* means comparisons where appropriate. Analyses could not be made across years due to large differences among years. Stepwise linear regression was used to evaluate the associations between wheat yield and disease levels (SAS User's Guide: Statistics Version 5, 1985, Cary, N.C.).

RESULTS AND DISCUSSON

Tillage had no impact on foliar or root disease severity and yield of wheat in the second 4-yr rotation of the study (Table 1). Although disease data were not collected in 1991, the yield data showed no differences among tillage treatments (zero - 2800 kg ha^{-1}, minimum - 2900 kg ha^{-1} , conventional - 3100 kg ha^{-1}). Tillage also had no effect on foliar disease severity during the first rotation cycle from 1987-1990, but during those years root disease severity was reduced in 3 of 4 yrs under minimum and zero tillage (Bailey et al. 1992). There were no consistent trends on the impact of rotation on foliar or root disease severity in wheat (Table 1), which was similar to observations made during the initial cycle (Bailey et al. 1992). The highest yields in wheat were obtained with the rotation using the greatest number of broad-leaved crops (Pea-Sw-Flax-Ww) (Table 1), relative to summerfallow-Sw-Sw-Ww (2 of 3 yr) and Sw-Sw-Flax-Ww (3 of 3 yr). In 1991, the yield of wheat was similar in summerfallow-Sw-Sw-Ww and Pea-Sw-Flax-Ww (both 3100 kg ha^{-1}), but lower with Sw-Sw-Flax-Ww (2500 kg ha^{-1}). There was no interaction between tillage practices and rotation in analysis of variance.

Examination of the individual crops grown in sequence showed that foliar disease severity and yield were greater in winter wheat than spring wheat (Table 2). Among the spring wheat treatments, yield was highest after either summerfallow or pea in all years. Foliar disease severity also tended to be lowest (only significant in 1993)

following these treatments. Low foliar disease severities on spring wheat grown after summerfallow or pea were also observed during the first rotation cycle in 1987-1990 (Bailey et al. 1992). In the Brown soil zone of Saskatchewan, however, leaf spot severity on spring wheat was more severe after summerfallow (Fernandez et al. 1998), although tillage method did not affect leaf spot severity.

Disease severity varied with the annual growing season environment. Foliar disease severity was lower in 1992 than in 1993-1994 (Table 2), which corresponded to seasonal precipitation. Precipitation from May to August in 1992 was 208mm, which was below the 82-year average (225mm); precipitation was above average in 1993 (255mm) and 1994 (279mm). The growing degree days from April to September ranged from a low of 1179 to a high of 1407 compared to the long-term mean of 1659. Cooler than average temperatures resulted in low to moderate root disease severity in all years.

The prevalence of leaf-spotting fungi on wheat during the growing season was not affected by tillage practice, but tillage did affect the prevalence of some root pathogens (Table 3).The incidence of *B. sorokiniana* and *G. graminis* var. *tritici* decreased with zero tillage, but there was no affect on *Fusarium* spp. From 1987-1990, zero tillage significantly reduced the visible disease symptoms of common root rot and take-all of wheat, but isolation of pathogens was not done (Bailey et al. 1992). Also in the earlier years, take-all was more severe in winter wheat than spring wheat (Bailey et al 1992). In 1994, the incidence of *G. graminis* var. *tritici* isolated from roots was greater in spring wheat than winter wheat (14% vs 3%, $P \leq 0.05$). Rotation had little impact on the prevalence of most wheat pathogens. The exceptions were lower levels of *S. tritici* (1993 only), higher levels of *Fusarium* spp. (1992 and 1994) and lower levels of *C. sativus* (1994) in the rotations using broad-leaved crops compared to continuous wheat with summerfallow (Table 3). Stepwise linear regression showed that disease had no impact on wheat yield in 1992 and 1993. In 1994, wheat yield was reduced by *S. tritici* and *G. graminis* var. *tritici* (yield = $2690 - 123_{St} - 833_{Ggt}$, $R^2 = 0.4$, $P \leq 0.03$).

Isolation of wheat pathogens in the early spring of 1993 from wheat stubble residue of the wheat crop grown in 1992 showed that *S. nodorum* was the only foliar pathogen more prevalent under zero tillage (3 lesions per 4 cm tissue) than conventional tillage (0.7 lesions) after an overwintering period (LSD-test, $P \leq 0.05$). *Stagnospora nodorum* sporulates most heavily on residue left on the soil surface for one overwintering period relative to residue

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that is either buried or left on the surface for two or more overwintering periods (Duczek et al. 1999).

The occurrence of foliar pathogens in the spring on the wheat stubble residue was not affected by rotation. The incidence of *C. sativus* from roots of the wheat stubble residue was highest in the rotation with continuous cereals and summerfallow and lowest in the two rotations with broad-leaved crops (13% vs mean of 5%, LSD-test, $P \leq 0.05$). The highest incidence of *C. sativus* occurred on wheat stubble when the previous crop (i.e. the crop in 1991 which was prior to the wheat crop from which the stubble was obtained) was either flax, summerfallow, spring wheat, or chem-fallow (range, 5-20%) and lowest with either pea or winter wheat (0-1%). Sporulation of *C. sativus* is usually highest on cereal residues and lower on oilseed and pulse crops, although it can sporulate on both flax and pea (Duczek et al 1996). The incidence of *Fusarium* spp. from roots of wheat stubble was highest in rotations that included broad-leaved crops (Sw-Sw-Flax-Ww, 31%; Pea-Sw-Flax-Ww, 28%) compared to continuous cereals with summerfallow (Summerfallow-Sw-Sw-Ww, 18%, LSD-test, $P \leq 0.05$). When the previous crop (relative to the crop producing the wheat stubble residue) was spring wheat, winter wheat, or flax, the incidence of *Fusarium* ranged from 23-40%. When the previous crop or treatment was pea, chem-fallow or summerfallow, the incidence of *Fusarium* spp. ranged from 0-7%. This suggests that the *Fusarium* species present were more pathogenic to wheat and flax than pea. It also suggests that the use of herbicides (as with chem-fallow) or tillage (as with summerfallow) may have role in decreasing *Fusarium* populations in the soil. In another study, zero tillage decreased populations of *Fusarium* spp. (Bailey et al. in review). The decline may have resulted from herbicide applications, lack of soil disturbance, biological changes in the microbial community or subtle shifts in the micro-environment associated with various tillage practices.

In field pea, *Mycosphaerella pinodes* (Berk & Blox.) was the only foliar pathogen at the site and fusarium root rot [*Fusarium* spp.] was the dominant root disease. Differences in foliar disease incidence and severity among tillage treatments were generally small, so only the final severity data are presented (Table 1). Conventional tillage resulted in a small decrease in severity compared to reduced tillage in both 1993 and 1994. Similarly, for root rot incidence and severity, there was no consistent differences among the tillage treatments, so only the final severity data are presented. In 1994, there was a substantial difference among tillage treatments in one of three ratings (not shown), but by the end of the season, this difference had disappeared (Table 1). Pea yields were similar among

tillage treatments in 1991- 1993 (Table 1 for 1992 and 1993). In 1991 the yield was 2700 kg ha $^{-1}$ in zero, 2800 kg ha $^{-1}$ in minimum and 2600 kg ha $^{-1}$ in conventional tillage. In 1994, pea yield with zero tillage was slightly greater. No other differences were noted.

During the second cycle of this long-term study, reduced tillage practices did not substantially change the severity of foliar or root diseases on wheat or field pea, or affect the relative incidence of foliar pathogens in wheat. However, reduced tillage practices decreased the incidence of *C. sativus* and *G. graminis* var. *tritici* on wheat roots. Disease severity of common root rot is influenced by temperature-related parameters (Bailey et al. 1989) such that the size of individual lesions increases during the growing season, as the host matures and temperatures increase. Pathogen incidence is influenced by moisture-related parameters (Bailey et al. 1989). Although severity is dependent upon incidence, the reverse is not true. Hence, incidence may be more appropriate for assessing the impact of disease management options such as crop rotation than severity. Rotations that incorporated broad-leaved crops, such as pea and flax, in alternate years with cereals had higher wheat yields than wheat grown in a summerfallow-cereal rotation. Rotation had little impact on the severity or prevalence of most diseases, with the exception of increasing the incidence of *Fusarium* spp. and decreasing the incidence of *C. sativus* in rotations with broad-leaved crops. The implications of these results for crop production are to reduce the risk of soil-borne diseases, such as common root rot and Fusarium diseases, by not growing flax and wheat in sequential rotation and providing a minimum break of one year between these crops to lower the levels of these pathogens in the soil. Changing from summerfallow-cereal based cropping systems to cereal-oilseed-cereal-pulse cropping sequences may reduce some root diseases and improve yield, without having a substantial impact on the risk of losses due to foliar diseases in wheat.

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DRAFT

Bailey, K.L. and Duczek, L.J. 1996. Managing cereal diseases under reduced tillage. Can. J. Plant Pathol. 18:159-167.

Bailey, K.L., Harding, H. and Knott, D.R. 1989. Disease progression in wheat lines and cultivars differing in levels of resistance to common root rot. Can. J. Plant Pathol. 11: 273-278.

Bailey, K.L., Gossen, B.D., Derksen, D.A. and Watson, P.R. 2000a. Impact of agronomic practices and environment on diseases of wheat and lentil. Can. J. Plant Sci. (in review)

Bailey, K.L., Johnston, A.M., Kutcher, H.R., Gossen, B.D. and Morrall, R.A.A. 2000b. Managing crop losses from foliar diseases with fungicides, rotation, and tillage in the Saskatchewan Parkland. Can. J. Plant Sci (In Press).

Bailey, K.L., Mortensen, K. and Lafond, G.P. 1992. Effects of tillage systems and crop rotations on root and foliar diseases of wheat, flax, and peas in Saskatchewan. Can. J. Plant Sci. 72:583-591.

Couture, L. 1980. Assessment of severity in foliage diseases of cereals in cooperative evaluation tests. Can. Plant Dis. Surv. 60:8-10.

Duczek, L.J., Jones-Flory, L.L., Reed, S.L., Bailey, K.L. and Lafond, G.P. 1996. Sporulation of *Bipolaris sorokiniana* on the crowns of crop plants grown in Saskatchewan. Can. J. Plant Sci. 76: 861-867.

Duczek, L.J., Sutherland, K.A., Reed, S.L., Bailey, K.L. and Lafond, G.P. 1999. Survival of leaf spot pathogens on crop residues of wheat and barley in Saskatchewan. Can. J. Plant Pathol. 21:165-173.

Fernandez, M.R., McConkey, B.G. and Zentner, R.P. 1998. Tillage and summerfallow effects on the leaf spot diseases of wheat in the semi-arid Canadian Prairies. Can. J. Plant Pathol. 20:376-379.

Horsfall, J.G. and Barrett, R.W. 1945. An improved grading system for measuring plant diseases. Phytopathology 35: 655 (Abstr.)

Juhnke, M.E., Mathre, D.E. and Sands, D.C. 1984. A selective medim for *Gaeumannomyces graminis* var. *tritici* Plant Dis. 68:223-236.

McFadden, W. 1991. Etiology and epidemiology of leaf spotting diseases in winter wheat in Saskatchewan. Ph.D . Thesis, University of Saskatchewan, Saskatoon. 151pp.

DRAFT

Stack, R.W. 1992. Bipolaris. Pages 94-99 in L.L. Singleton, J.D. Mihail, and C.M. Rush, Eds., Methods for research on soilborne phytopathogenic fungi. APS Press, St. Paul, Minnesota.

Tinline, R.D., Stauffer, J.G., and Dickson, J.G. 1960. *Cochliobolus sativus* III. Effect of ultraviolet radiation. Can. J. Bot. 38:275-282.

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Table 1. Effect of tillage and crop rotation on foliar and root disease severity and yield of wheat[¶] and field pea at Indian Head, SK from 1992-1994.

Variable or practice ¥	1992	1993	1994
	------ Tillage, Wheat ------		
Foliar severity			
Zero	7.9 a †	7.4 a	7.9 a
Minimum	7.6 a	7.4 a	7.7 a
Conventional	7.6 a	7.3 a	7.7 a
Root severity			
Zero	1.0 a	0.7 a	1.2 a
Minimum	1.1 a	0.8 a	1.2 a
Conventional	1.2 a	0.8 a	1.4 a
Yield ('000 kg ha^{-1})			
Zero	3.9 a	1.8 a	3.2 a
Minimum	4.1 a	1.9 a	3.2 a
Conventional	3.9 a	2.0 a	3.2 a
	----Rotation, Wheat ----		
Foliar severity			
Sf-Sw-Sw-Ww	7.7 a	7.3 a	7.8 a
Sw-Sw-Flax-Ww	7.9 a	7.6 a	7.7 a
Pea-Sw-Flax-Ww	7.1 b	7.3 a	7.6 a
Root severity			
Sf-Sw-Sw-Ww	1.0 a	0.7 ab	1.2 a
Sw-Sw-Flax-Ww	1.0 a	0.8 a	1.3 a
Pea-Sw-Flax-Ww	1.3 b	0.5 b	1.2 a
Yield ('000 kg ha^{-1})			
Sf-Sw-Sw-Ww	4.1 a	1.6 a	3.0 a
Sw-Sw-Flax-Ww	3.6 b	1.9 a	3.2 b
Pea-Sw-Flax-Ww	4.1 a	2.5 b	3.5 c
	-----Tillage, Pea-----		
Foliar severity			
Zero	nd	5.2 b	5.5 b
Minimum	nd	5.2 b	5.8 c
Conventional	nd	4.8 a	5.2 a
Root severity			
Zero	nd	1.5 a	1.2 a
Minimum	nd	1.6 a	1.0 a
Conventional	nd	1.7 a	1.0 a
Yield ('000 kg ha^{-1})			
Zero	2.8 a	2.7 a	2.4 b
Minimum	2.4 a	2.6 a	2.2 a
Conventional	2.4 a	2.6 a	2.2 a

† For each variable assessed, values in columns followed by the same letter are not significantly different at $P \leq 0.05$ based on Duncan's Multiple Range test; nd = not done.
¥ Foliar severity, 0-11 scale; Root severity, 0-3 scale; Sf, summerfallow; Sw, spring, wheat; Ww, winter wheat.
¶ Mean of spring and winter wheat crops.

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Table 2. Impact of foliar and root disease severity and yield on spring and winter wheat treatments in three crop rotations at Indian Head, SK from 1992-1994.

Rotation ¥	Wheat sequence	Foliar severity (0-11 scale)			Root severity (0-3 scale)			Yield ('000 kg ha^{-1})		
		1992	1993	1994	1992	1993	1994	1992	1993	1994
Sf<Sw_1<Sw_2<Ww	Sw_1	3.5a	6.5a	7.6a	1.4a	0.2ab	1.2ab	4.1c	2.0b	2.9b
	Sw_2	3.9a	7.1b	8.1a	1.0a	0.2ab	1.5b	3.7bc	1.3a	2.6a
	Ww	7.7b	8.2c	7.8a	3.0b	0.2ab	0.7a	4.4d	1.5a	3.7c
Sw_1<Sw_2<Flax<Ww	Sw_1	4.2a	7.4b	7.7a	1.5a	0.2ab	1.6b	3.2a	1.3a	2.8b
	Sw_2	4.3a	7.0b	7.5a	1.3a	0.3a	1.6b	3.5b	1.4a	2.8b
	Ww	7.1b	8.3c	7.8a	nd	0.0b	0.8a	4.5d	2.8c	4.0d
Pea<Sw<Flax<Ww	Sw	3.6a	6.2a	7.7a	1.1a	0.2ab	1.3ab	3.8bc	2.1b	2.8b
	Ww	6.8b	8.4c	7.6a	1.0a	0.0b	1.1ab	4.6d	2.8c	4.1d

† For each year, values in columns followed by the same letter are not significantly different at P=0.05 based on Duncan's Multiple Range test; nd, no data

¥ Sf, summerfallow; Sw, spring wheat; Ww, winter wheat

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Table 3. Impact of crop management on the prevalence of causal agents of foliar and root disease on spring and winter wheat at Indian Head, SK from 1992-1994.

Year	Crop management	Foliar Disease Complex ¶				Root disease complex ¶		
		%*Ptr*	%*St*	%*Sn*	%*Cs*	%*Cs*	%*Fus*	%*Ggt*
				---Tillage---				
1992	Zero	nd	57.5a†	41.9a	0.6a	10a	80a	nd
	Minimum	nd	51.2a	48.4a	0.4a	10a	80a	nd
	Conventional	nd	54.3a	45.2a	0.5a	30b	70a	nd
1993	Zero	14.9a	57.4a	27.3a	0.4a	20a	50a	nd
	Minimum	13.4a	58.9a	27.2a	0.5a	20a	40a	nd
	Conventional	9.4a	58.7a	31.6a	0.3a	40b	40a	nd
1994	Zero	24.7a	41.1a	34.2a	nd	20a	60a	5a
	Minimum	25.5a	31.1a	43.4a	nd	20a	60a	14b
	Conventional	22.0a	40.1a	37.9a	nd	20a	50a	11ab
				---Rotation---				
1992	Sf-Sw-Sw-Ww	nd	56.8a	42.6a	0.6a	30a	70a	nd
	Sw-Sw-Flax-Ww	nd	54.1a	45.5a	0.4a	20a	80b	nd
	Pea-Sw-Flax-Ww	nd	48.8a	50.9a	0.3a	20a	80b	nd
1993	Sf-Sw-Sw-Ww	12.2a	61.7b	25.7a	0.4a	30a	40a	nd
	Sw-Sw-Flax-Ww	11.5a	56.1ab	32.2a	0.2a	20a	40a	nd
	Pea-Sw-Flax-Ww	14.6a	56.3a	28.5a	0.6a	30a	50a	nd
1994	Sf-Sw-Sw-Ww	21.5a	38.5a	40.0a	nd	30b	50a	12a
	Sw-Sw-Flax-Ww	23.5a	35.2a	41.3a	nd	10a	50a	12a
	Pea-Sw-Flax-Ww	23.5a	39.3a	37.2a	nd	20ab	70b	5a

† In each year, values in columns followed by the same letter are not significantly different at $P \leq 0.05$ using a LSD test; nd, no data.

¶ *Ptr*, *Pyrenphora tritici-repentis*; *St*, *Septoria tritici*; *Sn*, *Stagnospora nodorum*; *Cs*, *Cochliobolus sativus*; *Fus*, *Fusarium* spp.; *Ggt*, *Gaeumannomyces graminis* var. *tritici*.

¥ Sf, summerfallow; Sw, spring, wheat; Ww, winter wheat; nd, no data

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Effect of tillage systems and crop rotations on root and foliar diseases of wheat and pea in Saskatchewan: Rotation Cycle 3, 1995-1998.

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Bailey, K.L., Gossen, B.D., Lafond, G.P. **Effect of tillage systems and crop rotations on root and foliar diseases of wheat and pea in Saskatchewan: Rotation Cycle 3, 1995-1998.** Can. J. Plant Sci xx: xx-xx. The long-term impact of tillage and rotation on wheat and pea diseases was examined in the third 4-yr rotation cycle of a study initiated in 1987. It monitored the disease severity and incidence of fungal species causing foliar leaf spot and root diseases under three rotations (summerfallow-spring wheat-spring wheat-winter wheat; spring wheat-spring wheat-flax-winter wheat; pea-spring wheat-flax-winter wheat) and three tillage practices (conventional, minimum, and zero) from 1995-1998. Reduced tillage increased foliar disease severity on wheat in 2 of 4 yrs, but had no impact on root disease severity or yield on wheat or pea, and no effect on foliar diseases of pea (primarily *Mycosphaerella pinodes*). Reduced tillage reduced the incidence of *Cochliobolus sativus* and *Gaeumannomyces graminis* var. *tritici* from wheat roots and increased the incidence of *Fusarium* spp. Rotation had little or no impact on most wheat diseases, but a larger impact on yield. Growing spring wheat after summerfallow or pea reduced foliar disease severity and improved yield. The rotations using more broad-leaved crops had improved yields over the summerfallow-cereal systems.

Key Words: rotation, tillage, root rot, leaf spot, wheat, pea

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Throughout the 1990's on the Canadian prairies, summerfallow acreage has declined while the acreage under reduced tillage management has increased. This change may increase the severity of leaf spot and root pathogens because it increases the amount of residue left on the soil surface. However, several recent studies in Saskatchewan have reported that tillage management generally does not affect severity of leaf spot diseases (Bailey et al. 1992, Bailey et al. 2000abc, Fernandez et al. 1998ab, Fernandez et al 1999). For disease management in reduced tillage systems, the importance of crop rotations has been emphasized (Bockus 1998). However, few studies have assessed the long-term impact of different tillage practices and crop rotations (i.e. continuous wheat vs cereal-oilseed or cereal-oilseed-cereal-pulse). The objective of this study was to assess the long-term impact of tillage and rotation on naturally-occurring foliar and root diseases in wheat and pea by examining the dynamics of disease severity and populations of causal agents in the third 4-yr rotation cycle (1995-1998) of a study initiated in 1987 (Bailey et al. 1992).

METHODS AND MATERIALS

This phase of the study was conducted from 1995-1998 at the Agriculture and Agri-Food Canada Experimental Farm, Indian Head, SK. The first 4-yr cycle of rotation ran from 1987-1990 and the second from 1991-1994. A detailed description of the agronomic methods are presented in Bailey et al. (1992). The tillage systems used were conventional (fall and spring tillage operations), minimum (one tillage operation in spring before seeding), and zero (no tillage). The rotations used were: 1) summerfallow-spring wheat (Sw)-Sw-winter wheat (Ww), 2) Sw-Sw-flax-Ww, and 3) pea-Sw-flax-Ww. Following the field season in 1998, the study was terminated.

Visual disease severity on leaves and roots of spring wheat and winter wheat were estimated on 25 plants collected at random from a diagonal path across each plot between July 20 and August 20 in 1995-1998. Root disease severity was estimated on the subcrown internode of each plant using a 0-3 scale, and the mean severity per plot was calculated (Stack 1992). Subcrown internode and crown pieces from each plant were washed for 1 hr under running tap water, then dried on absorbent paper. The root pieces were disinfested with 0.5%

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NaOCl for 3 min, rinsed twice with sterile distilled water, and then plated on minimal media (Tinline et al. 1960) containing 100 mg/L streptomycin sulfate and 50 mg/L vancomycin hydrochloride. The plates were incubated at 20°C and 12 hr day. The percentage of plants infected with red *Fusarium* spp. and *Bipolaris sorokiniana* (Sacc.) Shoem., was recorded 7-9 days after plating. Subcultures of the *Fusarium* spp. isolated from root lesions in 49 randomly selected plots in 1995 were grown on PDA and SNA media, identified to species based on conidial morphology and cultural characteristics, and re-tested for pathogencity on 'Katepwa' wheat (Singleton et al. 1992). *Gaeumannomyces graminis* (Sacc.) von Arx & Olivier var. *tritici* Walker was isolated on semi-selective media (Juhnke et al. 1984) containing L-DOPA which produces a black pigmentation in the medium under the infected tissue. The lower 1-cm of the main stem was surface sterilized with 1% silver nitrate for 30 sec followed by two sterile distilled water rinses and blotted dry before plating. Plates were incubated at 20°C with 12 h daylight for 5 days.

Leaf spot severity on cereals was assessed using a 0-11 scale (McFadden 1991), where 1 represents slight disease in the lower plant canopy and 11 is severe disease in both the lower and upper plant canopies, based on a modified scale from Couture (1980). The flag leaf and penultimate leaf from 10 plants per plot were cut into 4-cm-long segments. These leaf pieces were washed in running water for 1 h, disinfected for 1 min with 0.5% NaOCl, then plated on water agar containing 100 mg/L streptomycin sulfate and 50 mg/L vancomycin hydrochloride. The plates were incubated for 1 wk under a mixture of black light, black-blue light, and cool white fluorescent light. Fungal cultures were identified based on sporulation. Colonies of *Stagnospora nodorum* (Berk.) E. Castell. & Germano, *Septoria tritici* Roberge in Desmaz., *Pyrenophora tritici-repentis* (Died.) Drechs., and *Cochliobolus sativus* (Ito & Kurib.) Drechs. ex Dast. on each 4-cm segment were counted. The prevalence of a species was calculated by the number of colonies per unit area for that species, divided by the total colonies per unit area, and then expressed as a percentage.

In field pea, foliar and root rot incidence and severity were assessed on June 20, July 14 and August 16 in 1995; July 15 and August 15 in 1996; July 23 and August 6 in 1997; and July 7, July 21 and August 6 in 1998. On each sampling date, 25 plants were collected (5 plants per location, 5 locations per subplot) and rated for foliar and root disease severity. Foliar diseases were rated using the Horsfall-Barrett scale (Horsfall and Barrett 1945). In

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addition, whole-plot foliar disease ratings were made at flowering and seed filling. Root rot was assessed using a 0-3 scale, where 1 represents 1-25% of the tap root diameter rotted, and 3 represents > 50% rotted (modified from Hwang et al. 1994). For all diseases, pathogens were identified based on symptoms and identification was confirmed by occasional plating of surface-disinfested samples onto PDA.

Differences in the pathogen populations and disease severity in each year were compared using analysis of variance, with *a priori* means comparisons where appropriate. Analyses could not be made across years as there were large differences among years. Stepwise linear regression was used to evaluate the associations between yield and disease (SAS User's Guide: Statistics Version 5, 1985, Cary, N.C.).

RESULTS

Reduced tillage practices increased foliar disease severity in wheat in 1995 and 1996, but had no impact in 1997 and 1998 (Table1). Tillage practice did not affect root disease severity or yield of wheat in most years. Foliar and root disease severity on wheat was similar in all rotations. Wheat yields increased with rotations using broad-leaved crops as compared to summerfallow-cereal systems in 2 of 4 yrs. There were no interactions between tillage practice and rotation.

Examination of the individual crops grown in sequence showed that foliar and root disease severity were higher in winter wheat than spring wheat (Table 2). Yields of winter wheat were lower than spring wheat in the summerfallow-cereal rotation, but higher than spring wheat in the rotations using broad-leaved crops (except in 1998). Among the spring wheat treatments, yield was highest after either summerfallow or pea in 3 of 4 yrs (1995-1997); foliar disease severity was lowest following summerfallow in 1995-1997 and pea in 1996-1997. Crop rotation had no effect on root severity.

Precipitation and growing degree days, which were measured on site, were variable from year to year. Precipitation from May to August was below the 82-year average (225mm) in 1996 (131mm) and 1997 (124mm), and above average in 1995 (297mm) and 1998 (356mm). Warmer-than-average temperatures resulted in the growing degree days from April to September ranging from 1841 (1995) to 2840 (1997) compared to the long-term

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mean of 1659. Warm and dry conditions in 1997 reduced foliar disease severity (mean 5.9 vs 9.7 in other years). In contrast, the cool, moist conditions in 1995 increased the severity of root disease (Table 1). In some years, certain diseases or causal agents were associated with losses in wheat yield: i) Yield $_{1995}$ = 2225 - 310 $_{\text{common root rot severity}}$ + 158 $_{\text{leaf spot severity}}$, R^2 = 0.13, $P \leq 0.05$, ii) Yield $_{1996}$ = 4318 - 121 $_{P.\ tritici\text{-}repentis}$ - 66 $_{S.\ nodorum}$ - 481 $_{C.\ sativus}$, R^2 = 0.25, $P \leq 0.05$, iii) Yield $_{1997}$ = 1140 - 197 $_{S.\ tritici}$, R^2 = 0.26, $P \leq 0.05$, and iv) Yield $_{1998}$ = 2724 - 3014 $_{C.\ sativus}$ - 62 $_{S.\ tritici}$, R^2 0.29, $P \leq 0.001$.

The prevalence of leaf-spotting fungi on wheat during the growing season was not affected by tillage treatment, except that the incidence of *S. nodorum* increased under reduced tillage in 1997 (Table 3). In 1995, the incidence of *C. sativus* from roots was lower under reduced tillage management, whereas the incidence of *Fusarium* spp. increased with reduced tillage in 1996 and 1997. The majority of *Fusarium* isolates examined were pathogenic to wheat (57%) and were identified as *F. equisetti, F. culmorum, F. acuminatum*, and *F. graminum*. The pathogen *G. graminis* var. *tritici*, which causes take-all of wheat, was only present in 1995 and 1996; reduced tillage decreased the incidence of this pathogen in 1995 (Table 3).

The rotation that included pea-spring wheat-flax-winter wheat had the lowest incidence of *S. tritici* (1997 and 1998), *S. nodorum* (1996 and 1997) and *C. sativus* (from the root disease complex, 1996) compared to the summerfallow-cereal rotation (Table 3). In 1995, this same diverse broad-leaved crop rotation had a higher incidence of *Fusarium* spp. The incidence of *G. graminis* var *tritici* was not influenced by crop rotation.

In field pea, *Mycosphaerella pinodes* (Berk & Blox.) was the dominant foliar pathogen and fusarium root rot (*Fusarium* spp.) was the dominant root disease at the site each year. There were no substantial differences in incidence or severity of either disease among tillage treatments at any date, so only the final severity assessments are presented (Table 1). In 1995, mycosphaerella blight severity was low throughout the season, and blight severity under zero-tillage was slightly higher than for the other two tillage regimes. In 1996, blight severity was low to moderate, and there were no differences among tillage systems. There were no differences in fusarium root rot severity or yield among tillage treatments in any year.

DISCUSSION

During the third (final) cycle of this trial, levels of foliar and root diseases in wheat were high enough to

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cause losses in yield. Reduced tillage practices had little or no impact on foliar disease severity (Table 1). This was consistent with observations in the first two cycles of the study, where leaf spot severity increased under reduced tillage management in only 1 of 8 years (Bailey et al. 1992, 2000a). In previous studies in the Brown soil zone of Saskatchewan, tillage management system did not affect foliar disease severity (Fernandez et al. 1998a, 1999).

Similarly, tillage system had no impact on root disease severity in 1995-1998 (Table 1). In years when the pathogens were present during the third cycle, *C. sativus* was less prevalent under reduced tillage management in 1 of 4 years, and the prevalence of *G. graminis* var. *tritici* was reduced in 1 of 2 years (Table 3). Over the entire study, *C. sativus* was significantly less prevalent or disease was less severe under reduced tillage management in 6 of 11 years and in 3 of 4 years for *G. graminis* var. *tritici* (Bailey et al. 1992; Bailey et al. 2000a). The incidence of *Fusarium* spp. increased under reduced tillage in 2 of 4 years in Cycle 3, but levels were not affected by tillage management in Cycle 2 (Bailey et al. 2000a). A weak association with tillage management has been observed in other studies (Miller et al. 1998, Bailey et al. 2000b).

The most diverse crop rotation (pea-spring wheat-flax-winter wheat) produced a higher wheat yield than the summerfallow-cereal based system in 2 of 4 years in Cycle 3 (Table 1), 2 of 4 years in Cycle 2 (Bailey et al. 2000a), and 1 of 4 years in Cycle 1 (Bailey et al. 1992). Yield in the other rotation (spring wheat-spring wheat-flax-winter wheat) was often intermediate. In a previous study in western Canada, grain yield was higher and populations of *C. sativus* and *G. graminis* var. *tritici* were lower in wheat planted after canola or flax than after cereals (Sturz and Bernier 1989).

In the present study, there were no differences in wheat disease severity among the rotation treatments in Cycle 3 (Table 1), and few consistent trends across the three rotation cycles. For example, mean foliar disease severity on wheat in the most diverse rotation was lower than in the summerfallow-cereal rotation in only two years (1990 and 1992). Similarly, root rot severity on wheat was higher in the diverse rotation than in the summerfallow-cereal rotation in 1987 and 1992, but lower in 1989 and 1993 (Bailey et al 1992, Bailey et al. 2000a). However, growing spring wheat after spring wheat in the summerfallow-cereal crop rotation increased foliar disease severity in 3 of 4 years in Cycle 3 (Table 2). This trend was also present in the previous cycles; foliar disease severity was lower on spring wheat after summerfallow or pea than on spring wheat after wheat in 10 of 11 years (Table 2,

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Bailey et al. 1992, Bailey et al. 2000a). Spring wheat was not grown after flax in these rotations so the impact of this crop could not be determined. In contrast, in a previous study conducted in the brown soil zone, the severity of leaf spot of wheat caused by *Pyrenophora tritici-repentis* was higher after summerfallow than after either continuous wheat or a non-cereal crop (Fernandez et al. 1998a, 1999). Wheat grown after flax, lentil or another non-cereal consistently has less leaf spot disease (Fernandez et al. 1998b; Bailey et al. 2000a,c).

The results for field pea in Cycle 3 are similar to those from Cycles 1 and 2 (Table 1, Bailey et al. 1992, 2000a). *Mycosphaerella pinodes* (Berk & Blox.) was the dominant, and generally the only, foliar pathogen at the site; fusarium root rot [*Fusarium* spp.] was the dominant root disease, although *Pythium* spp. would have been difficult to detect in these assessments (Hwang et al. 2000). Tillage system did not have a substantial impact on the incidence (data not shown) or severity of foliar or root diseases of field pea in Cycle 3 (Table 1) or in previous cycles. Previous studies had shown that survival of the *M. pinodes* is reduced when infected residue is buried (Dickinson and Sheridan 1968, Sheridan 1973), so this was an unexpected result for mycosphearella blight. We conclude that tillage regime had little or no impact on mycosphaerella blight and fusarium root rot of field pea grown in 4-yr rotations with cereals or flax. However, the cropping history of the study area prior to the trial was primarily cereals and summerfallow in a relatively weed-free environment, with no prior history of pea production. Field pea was grown on only 1/12 of the plot area in any year, and this limited area was reseeded (using high quality, certified seed) to field pea only every fourth year. Given these constraints to disease introduction and development, it is not surprising that the community of pathogens on field pea at this site was extremely simple. These results also illustrate how optimum management can limit the introduction and spread of diseases on crops such as field pea. The results of this longer-term study supports observations from a 4-yr study of more diverse cropping rotations at the same site (Bailey et al. 2000a). The study of diverse cropping rotations showed that tillage system did not affect foliar or root rot incidence or severity in field pea or lentil grown in 4-yr rotations.

One of the major problems in the design, implementation and analysis of epidemiological studies is the confounding impact of migration of inoculum in and out of individual plots (inter-plot interference). A study on diseases of cereals indicated that inter-plot interference was minimal for splash-dispersed pathogens in plots of the size used in this trial, but that some interference should be expected from air-borne pathogens unless the plots were

substantially larger (Burleigh and Loubane 1984). Our results support the conclusions from this study. Most of the important pathogens in our study were either soil-borne or splash-dispersed, and were not expected to move quickly among plots. In fact, there was no indication of substantial disease gradients in any year of the study for any pathogen. However, *M. pinodes* was found in every field pea plot in each year of the study, even though pea had not been grown previously in the study area. The most likely explanation is that the pathogen was introduced to the site via wind-borne ascospores from infected residue in adjacent fields. Another potential source of this inoculum is seed-borne infection, but we feel that this is unlikely, given that the disease was present every year. If, as this suggests, airborne ascospores are an important source of inoculum for this pathogen, inter-plot interference may have had an important impact on disease assessments, and may explain, at least in part, the relatively small impact that tillage system had on disease incidence and severity.

In conclusion, changing to reduced tillage practices in Saskatchewan is not expected to substantially increase disease severity, and associated yield losses, from foliar leaf spot diseases of wheat or on diseases of field pea. However, it will likely affect the relative importance of several root pathogens of wheat. Reduced tillage may reduce populations of *C. sativus* but increase populations of *Fusarium* spp. on wheat roots. These changes in relative prevalence generally off-set each other and are unlikely to have a substantial impact on root disease severity or yield losses. Reduced tillage systems also lowered the importance of take-all. Although take-all occurs only sporadically in western Canada, the shift to zero-till may help to limit the occurrence of this disease problem. Rotation had a limited impact on disease severity and the prevalence of fungal pathogens, but wheat grown in diversified crop rotations had consistently higher yields than wheat following wheat. The greater impact of crop rotation on disease management came from using particular cropping sequences, such as growing wheat after summerfallow or pea to reduce the impact of foliar diseases.

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Bailey, K.L., Gossen, B.D. and Lafond, G.P. 2000a. Effect of tillage systems and crop rotation on root and foliar diseases of wheat and pea in Saskathchewan: rotation Cycle 2, 1991-1994. Can J. Plant Sci. (in review)

Bailey, K.L., Gossen, B.D., Derksen, D.A. and Watson, P.R. 2000b. Impact of agronomic practices and environment on diseases of wheat and lentil. Can. J. Plant Sci. (in review)

Bailey, K.L., Johnston, A.M., Kutcher, H.R., Gossen, B.D. and Morrall, R.A.A. 2000c. Managing crop losses from foliar diseases with fungicides, rotation, and tillage in the Saskatchewan Parkland. Can. J. Plant Sci (In Press).

Bailey, K.L., Mortensen, K. and Lafond, G.P. 1992. Effects of tillage systems and crop rotations on root and foliar diseases of wheat, flax, and peas in Saskatchewan. Can. J. Plant Sci. 72:583-591.

Boekus, W. 1998. Control strategies for stubble-borne pathogens of wheat. Can. J. Plant Pathol. 20: 371-375.

Burleigh, J.R. and Loubane, M. 1984. Plot size effects on disease progress and yield of wheat infected by *Mycosphaerella graminicola* and barley. Phytopathology 74: 545-549

Couture, L. 1980. Assessment of severity in foliage diseases of cereals in cooperative evaluation tests. Can. Plant Dis. Surv. 60:8-10.

Dickinson, C.H. and Sheridan, J.J. 1968. Studies on the survival of *Mycosphaerella pinodes* and *Ascochyta pisi*. Ann. Appl. Biol. 62: 473-483

Fernandez, M.R., McConkey, B.G. and Zentner, R.P. 1998a. Tillage and summerfallow effects on the leaf spot diseases of wheat in the semi-arid Canadian Prairies. Can. J. Plant Pathol. 20:376-379.

Fernandez, M.R., McConkey, B.G. and Zentner, R.P. 1999. Effects of tillage method and fallow frequency on leaf spotting diseases of spring wheat in the semiarid Canadian prairies. Soil & Tillage Res. 50: 259-269.

Fernandez, M.R., Zentner, R.P., McConkey, B.G. and Campbell, C.A. 1998b. Effects of crop rotations and fertilizer management on leaf spotting diseases of spring wheat in southwestern Saskatchewan. Can. J. Plant Sci. 78: 489-496.

Hwang, S.F., Gossen, B.D., Turnbull, G.D., Chang, K.F., Howard, R.J. and Thomas, A.G. 2000. Effect of temperature, seeding date and seed treatments on damping-off and root rot of field pea caused by *Pythium* spp. Can J. Plant Pathol. (accepted).

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Juhnke, M.E., Mathre, D.E. and Sands, D.C. 1984. A selective medium for *Gaeumannomyces graminis* var. *tritici* Plant Dis. 68:223-236.

McFadden, W. 1991. Etiology and epidemiology of leaf spotting diseases in winter wheat in Saskatchewan. Ph.D . Thesis, University of Saskatchewan, Saskatoon. 151pp.

Miller, J.D., Culley, J., Fraser, K., Hubbard, S., Meloche, F., Ouellet, T., Seaman, W.L., Seifert, K.A., Turkington, K. and Voldeng, H. 1998. Effect of tillage practice on fusarium head blight of wheat. Can. J. Plant Pathol. 20: 95-103.

Sheridan, J.J. 1973. The survival of *Mycosphaerella pinodes* on pea haulm buried in soil. Ann. Appl. Biol. 75: 195-203

Stack, R.W. 1992. *Bipolaris*. Pages 94-99 in L.L. Singleton, J.D. Mihail, and C.M. Rush, Eds., Methods for research on soilborne phytopathogenic fungi. APS Press, St. Paul, Minnesota.

Sturz, A.V., and Bernier, C.C. 1989. Influence of crop rotations on winter wheat growth and yield in relation to the dynamics of pathogenic crown and root rot fungal complexes. Can. J. Plant Pathol. 11:114-121.

Tinline, R.D., Stauffer, J.G., and Dickson, J.G. 1960. *Cochliobolus sativus* III. Effect of ultraviolet radiation. Can. J. Bot. 38:275-282.

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Table 1. Effect of tillage and crop rotation on foliar and root disease severity and yield of wheat ¶ and field pea at Indian Head, SK from 1995-1998.

Variable or practice ¥	1995	1996	1997	1998
		------Tillage, Wheat------		
Foliar severity				
Zero	8.4 b †	10.5 b	6.0 a	10.6 a
Minimum	7.9 a	10.6 b	5.8 a	10.6 a
Conventional	7.7 a	10.3 a	6.0 a	10.6 a
Root severity				
Zero	1.7 a	1.1 a	0.9 a	1.2 a
Minimum	1.7 a	1.1 a	0.9 a	1.1 a
Conventional	1.7 a	1.3 a	0.8 a	1.4 a
Yield (000's kg ha^{-1})				
Zero	2.7 a	3.3 a	1.4 a	1.8 a
Minimum	2.7 a	3.3 a	1.4 a	1.9 a
Conventional	3.0 b	3.4 a	1.3 a	2.0 a
		------ Rotation, Wheat------		
Foliar severity				
Sf-Sw-Sw-Ww	7.7 a	10.4 a	5.9 a	10.5 a
Sw-Sw-Flax-Ww	7.9 a	10.5 a	5.9 a	10.6 a
Pea-Sw-Flax-Ww	8.7 a	10.4 a	5.8 a	10.7 a
Root severity				
Sf-Sw-Sw-Ww	1.6 a	1.2 a	0.8 a	1.1 a
Sw-Sw-Flax-Ww	1.7 a	1.2 a	0.9 a	1.1 a
Pea-Sw-Flax-Ww	1.9 a	1.1 a	0.8 a	1.3 a
Yield (000's kg ha^{-1})				
Sf-Sw-Sw-Ww	2.7 a	2.9 a	1.5 a	1.7 a
Sw-Sw-Flax-Ww	2.7 a	3.4 b	1.3 a	2.0 a
Pea-Sw-Flax-Ww	3.1 b	3.8 c	1.5 a	1.9 a
		------Tillage, Pea------		
Foliar severity				
Zero	2.5 b	2.6 a	4.0 a	5.3 a
Minimum	1.8 a	2.6 a	4.0 a	5.0 a
Conventional	1.7 a	2.7 a	4.0 a	5.1 a
Root severity				
Zero	1.2 a	1.5 a	1.5 a	0.8 a
Minimum	1.3 a	1.3 a	1.3 a	0.9 a
Conventional	1.4 a	1.3 a	1.3 a	0.8 a
Yield (000's kg ha^{-1})				
Zero	2.6 a	3.3 a	1.7 a	3.5 a
Minimum	2.8 a	3.7 a	1.5 a	3.0 a
Conventional	2.6 a	3.4 a	1.3 a	2.8 a

† For each variable assessed, values in columns followed by the same letter are not significantly different at $P \leq 0.05$ based on Duncan's Multiple Range test; nd = not done.
¥ Foliar severity, 0-11 scale; Root severity, 0-3 scale; Sf, summerfallow; Sw, spring wheat; Ww, winter wheat.
¶ Mean of spring and winter wheat crops.

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Table 2. Impact of foliar and root disease severity and yield on spring and winter wheat treatments in three crop rotations at Indian Head, SK from 1995-1998.

Rotation ¥	Wheat sequence	Foliar severity (0-11 scale)				Root Severity (0-3 scale)				Yield (000's kg ha^{-1})			
		1995	1996	1997	1998	1995	1996	1997	1998	1995	1996	1997	1998
Sf<Sw_1<Sw_2<Ww													
	Sw_1	5.7a	9.1a	4.3a	10.1a	1.2d	1.1a	0.7a	0.5a	3.2c	3.3b	2.0c	2.1bcd
	Sw_2	6.5b	10.6d	6.3d	10.4a	1.4cd	1.1a	0.8a	0.5a	2.6b	2.9a	1.2a	2.3cd
	Ww	10.9c	11.0e	7.3e	11.0b	2.3a	1.4a	nd	2.1b	2.4a	2.7a	1.2a	0.8a
Sw_1<Sw_2<Flax<Ww													
	Sw_1	6.3b	9.9b	5.9cd	10.3a	1.6c	1.4a	0.9a	0.7a	2.3a	2.7a	1.0a	2.3cd
	Sw_2	6.5b	10.3c	5.6bc	10.5a	1.4cd	1.2a	0.9a	0.7a	2.3a	2.7a	1.2a	2.1bcd
	Ww	10.9c	11.0e	6.4d	11.0b	1.9b	1.1a	nd	1.8b	3.4c	4.0c	1.6b	1.7b
Pea<Sw<Flax<Ww													
	Sw	6.2b	9.2a	5.0b	10.4a	1.6c	1.0a	0.8a	0.7a	2.7b	3.3b	1.4b	2.2a
	Ww	11.0c	11.0e	6.6d	11.0b	2.2ab	1.2a	nd	1.9b	3.5c	4.1c	1.5b	1.6b

† For each year, values in columns followed by the same letter are not significantly different at P=0.05 based on Duncan's Multiple Range test.

¥ Sf, summerfallow; Sw, spring, wheat; Ww, winter wheat

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Table 3. Impact of crop management on the prevalence of causal agents of foliar and root disease on spring and winter wheat at Indian Head, SK from 1995-1998.

Year	Crop management	Foliar Disease Complex ¶				Root disease complex ¶		
		%*Ptr*	%*St*	%*Sn*	%*Cs*	%*Cs*	%*Fus*	%*Ggt*
				---Tillage---				
1995	Zero	nd ¥	nd	nd	nd	49a †	70a	9a
	Minimum	nd	nd	nd	nd	48a	68a	12a
	Conventional	nd	nd	nd	nd	66b	59a	19b
1996	Zero	11a	56a	32a	1a	59a	83b	50a
	Minimum	15a	59a	23a	3ab	56a	77ab	48a
	Conventional	18a	61a	17a	4b	66a	76a	51a
1997	Zero	16a	45a	35b	4a	23a	28b	nd
	Minimum	13a	50a	34b	3a	19a	28b	nd
	Conventional	19a	55a	22a	4a	25a	22a	nd
1998	Zero	22a	54a	23a	1a	11a	27a	nd
	Minimum	21a	54a	24a	1a	11a	28a	nd
	Conventional	27a	44a	28a	1a	11a	22a	nd
				---Rotation---				
1995	Sf-Sw-Sw-Ww	nd	nd	nd	nd	60a	60a	13a
	Sw-Sw-Flax-Ww	nd	nd	nd	nd	54a	65a	13a
	Pea-Sw-Flax-Ww	nd	nd	nd	nd	47a	75b	10a
1996	Sf-Sw-Sw-Ww	13a	56a	28b	3a	68b	79a	49a
	Sw-Sw-Flax-Ww	17a	57a	24ab	2a	57a	78a	52a
	Pea-Sw-Flax-Ww	12a	69a	17a	2a	54a	80a	47a
1997	Sf-Sw-Sw-Ww	15a	54b	27b	4b	21a	27a	nd
	Sw-Sw-Flax-Ww	15a	50a	32b	3a	22a	25a	nd
	Pea-Sw-Flax-Ww	24a	50a	22a	4b	24a	29a	nd
1998	Sf-Sw-Sw-Ww	22a	53b	24a	1a	11a	25a	nd
	Sw-Sw-Flax-Ww	23a	51ab	25a	1a	11a	25a	nd
	Pea-Sw-Flax-Ww	26a	47a	26a	1a	13a	26a	nd

† In each year, values in columns followed by the same letter are not significantly different at $P \leq 0.05$ using a LSD test; nd, no data.

¶ *Ptr*, *Pyrenphora tritici-repentis*; *St*, *Septoria tritici*; *Sn*, *Stagnospora nodorum*; *Cs*, *Cochliobolus sativus*; *Fus*, *Fusarium* spp.; *Ggt*, *Gaeumannomyces graminis* var. *tritici*.

¥ Sf, summerfallow; Sw, spring, wheat; Ww, winter wheat; nd, no data